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ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

VOL. V. No. 6 JUNE, 1944

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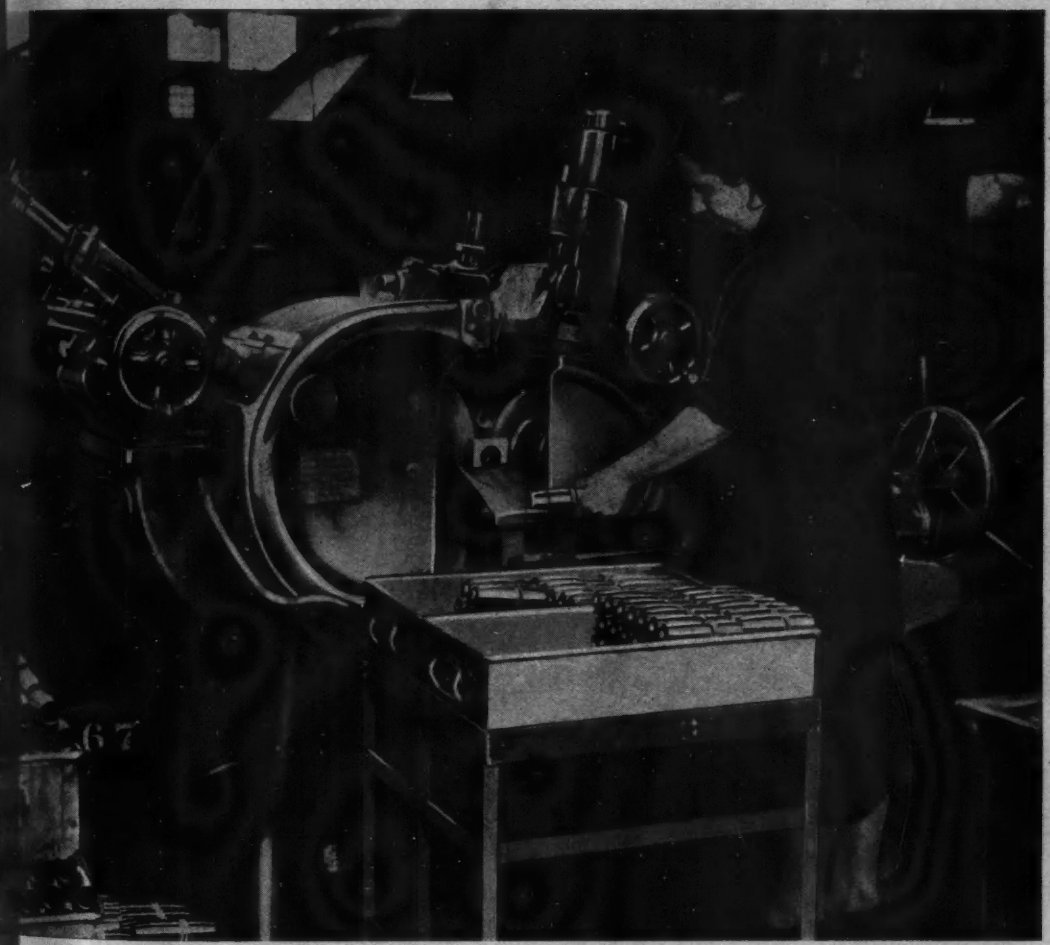

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Distribution – – E. & F. N. SPON, LTD., 57, Haymarket, London, S.W.1
Telephone : Whitehall 1860. Telegrams : Fenspon, Lesquare, London

Editorial Dept. – – 120, Wigmore Street, London, W.1. – Telephone : Welbeck 9357

Subscriptions to : ENGINEERS' DIGEST LTD., 120, Wigmore Street, London, W.1, or
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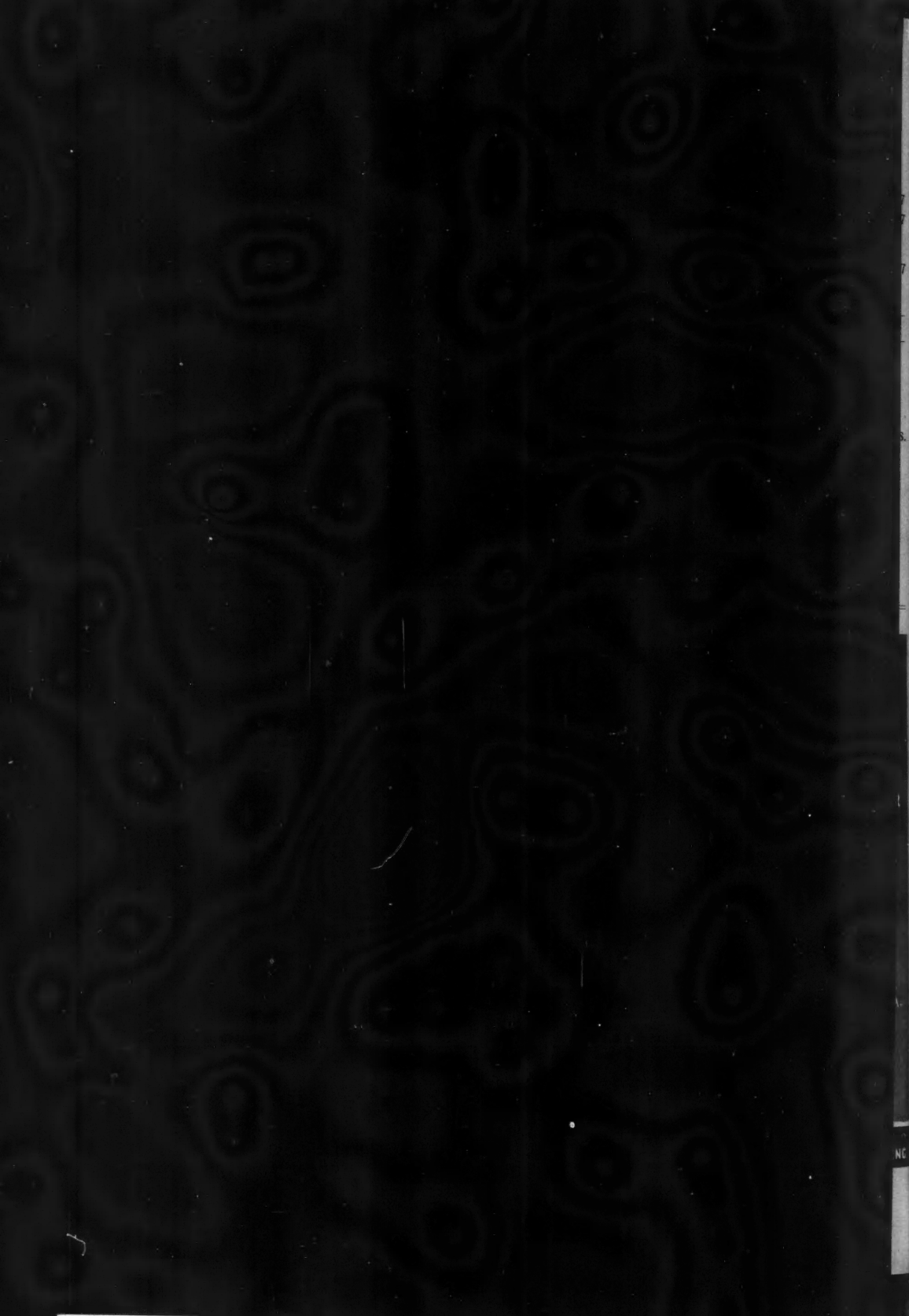

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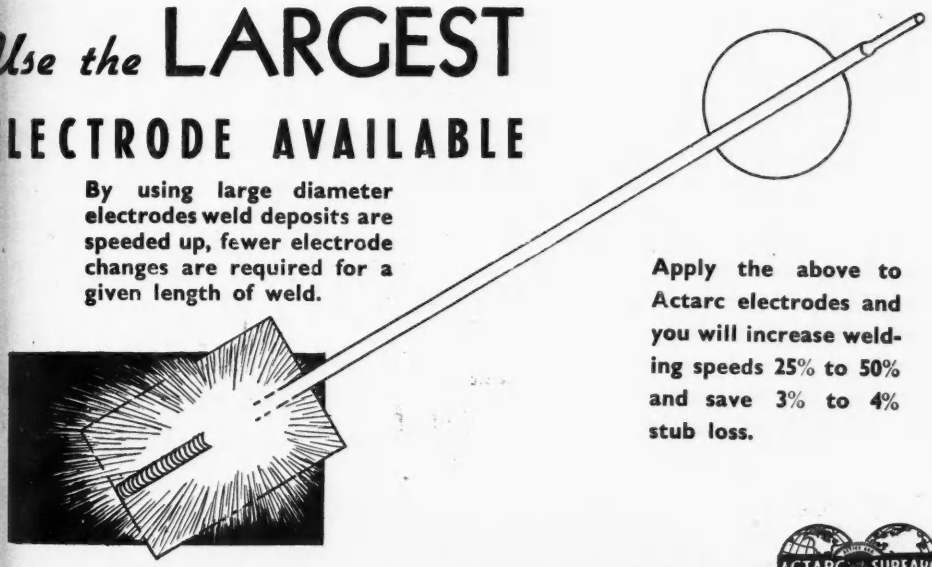

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MATERIALS AND THE SCIENCE OF MATERIALS

By DR. H. STÄGER. (From *Schweizer Archiv*, Vol. 10, No. 1, January, 1944, pp. 1-28).

THE magnitude and increasing scope of technical developments has made it necessary to resort to a progressive augmentation of the working stresses to be carried by structural materials; and very frequently these stresses are combined stresses. Thus, for instance, in large scale chemical syntheses the chemical reactions take place at high temperature, and often in conjunction with very high pressures. Materials are, therefore, required which safeguard operation under these conditions, particularly as continual exposure of the materials to high temperatures may lead to their fracture under load.

It has been no easy task for the metallurgist to develop alloys capable of withstanding complex stresses, especially as the reacting gas mixtures contain various constituents differing in corrosive action upon the material. In this respect, painstaking investigations have to be carried out on the materials intended for such uses. Mathematical stress analysis alone is not therefore sufficient, particularly as it is now known that at elevated temperatures metallic materials exhibit properties fundamentally different from those registered under the conditions ordinarily employed hitherto. Nor can these phenomena be mathematically analysed as yet. To achieve success, therefore, the most variegated branches of technological science must be drawn upon.

The era of purely mechanistic conceptions of design principles and of material properties has now passed; and it is a matter of satisfaction to note a trend towards the treatment of problems from a larger point of view, thus abandoning a tendency towards the accumulation of a maze of more or less unrelated detail. The methodology of natural science has made it possible to develop analytical methods which enable the gleaning of a certain amount of information on the smallest constituents of matter; but, as M. Planck has pointed out, the true nature of a thing cannot be found by dissecting it into progressively smaller constituents and then studying each one separately. This can only lead to the neglect of significant properties. On the contrary, matter must always be considered in its entirety, and the co-relationships of the individual constituents must be kept in mind. An entirety is always something more than a mere sum total of separate constituents.

This maxim must above all be taken into consideration in the investigation of materials, since a purely analytical treatment will never lead to the knowledge required with regard to compact-dispersed materials. Former methods of technology cannot, therefore, be considered satisfactory, nor is a "science of materials" simply a modification of technology; far more than that, it is a concentration and co-ordination of the variegated findings of "*material* science." While technology is defined as the discipline of forming and working materials, the science of materials represents the sum total of the manifold individual disciplines of natural science, co-related and co-ordinated from the aspect of the utilisation of matter in the most varied conditions and states of dispersion as structural material of modern technical practice.

Having thus defined the position of "Science of Materials" within the scope of this enquiry, the question must be asked as to what means are available to obtain the knowledge required?

Several methods are available for the analytical treatment of the compact-dispersed state of matter which permit an advance towards an insight into the discrete-dispersed state of matter. In this respect, the electron-microscope is an important means of advance, increasing as it does the maximum resolving power of the ordinary type of microscope a hundredfold.

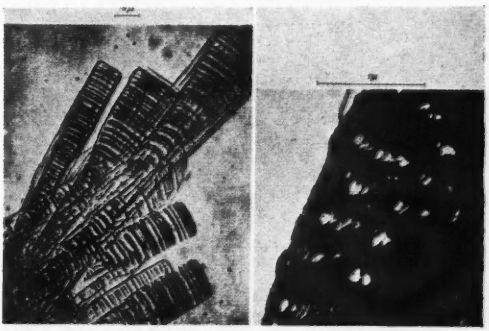


Fig. 1 (left). **Structure of β-polyoxymethylene after caustic soda solution treatment as seen in microscope.**
Fig. 2 (right). **The same, as seen in electron microscope.**

As exemplified by Fig. 1, microscopic inspection of synthetic organic compounds shows the formation of fibrous structure produced by the linear arrangement of the macro-molecules, the structure being similar to that observed in natural products. Here the macro-molecular fibrous derivatives of β-poly-oxymethylene produced by the treatment of the latter with 2.5-n-caustic soda solution are seen to be arranged in fascicular fashion. However, even when employing maximum resolving power of the microscope, only qualified deductions can be made with regard to the degree of polymerisation and to the molecular weight. Investigation by means of the electron-microscope, as shown in Fig. 2, therefore represents a considerable advance, permitting a more exact determination of the degree of polymerisation. With regard to metallography, the progress made in micro-photographic technique in conjunction with the electron-microscope is evidenced by Figs. 3 and 4.

The form taken by matter in most cases depends on genetic conditions, and for a certain class of reactions the morphology will therefore be dependent upon the genesis. The very considerable differences in configuration which may occur are illustrated by Fig. 5, in which electron-microscopically obtained micro-photographs of magnesium oxide and zinc oxide fume particles are juxtaposed.

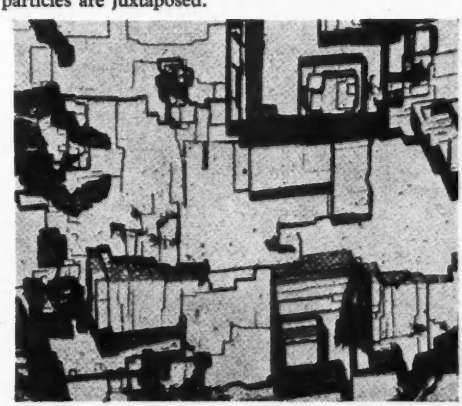


Fig. 3. Etched surface of aluminium, electron-microscope microphotograph. Magnification 4400X.

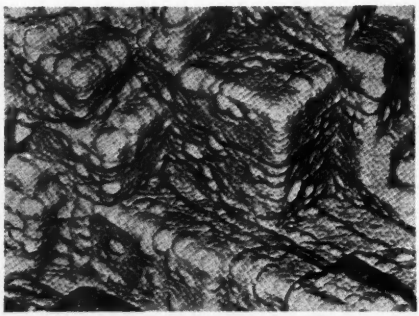


Fig. 4. Etched surface of aluminium, electron microscope. Magnification 20,000X.

To arrive at an explanation of the properties of materials, two methods can be followed: (*a*) the analytical treatment which has already been referred to, or (*b*) the synthetic treatment. The latter may be illustrated by taking the case of magnetic properties. According to the atomic structure of a material, its magnetic behaviour may be paramagnetic or diamagnetic. In the case of paramagnetism, the induction in the material is greater than that in vacuum, while in the case of diamagnetism it is smaller. The nucleus of the atom carrying a positive charge is considered to be surrounded by spinning negative electrons revolving in fixed orbits, the number of the electrons corresponding to the positive charge of the nucleus. It is the sum total of the momenta of the electrons in their orbits which determines the magnetic properties of the material. A material with non-symmetrical atomic structure in which the sum total of the momenta differs from zero, will show paramagnetic characteristics, while in the diamagnetic material this sum total is zero.

In order to explain ferromagnetism as a special case of paramagnetism, the atomic structure must be considered in the fixed crystallised state. Under such a condition each atom is affected by the presence of its neighbours; and it becomes clear that "the entirety is something quite different from a mere sum total of its components." If the distance between the atoms is small, a mutual atomic influence takes place manifesting itself by chemical combination. Changes in the distribution of the electrons and in their energy level also take place. Ferromagnetism has been shown to be the property of a number of electrons combined in an elemental assembly rather than of the individual atom. In an assembly of this kind the individual atomic spins (originating from the electron) are in parallel orientation, the directing force being given by the so-called exchange-integral, which is positive in the case of ferromagnetic

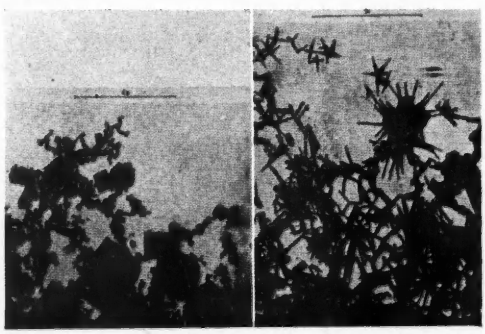


Fig. 5. Magnesiumoxide fumes (l.h.) and zincoxide (r.h.), electron-microscope.

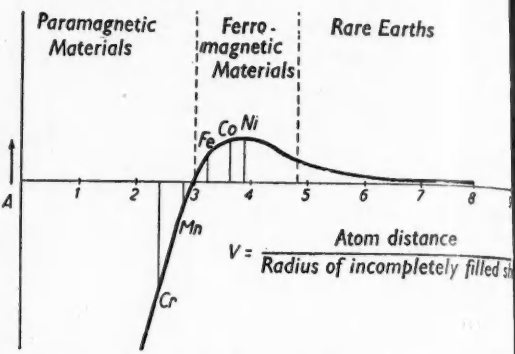


Fig. 6. Exchange-integral vs. distance between atoms of paramagnetic materials.

materials. The inter-atomic distance is, however, also of influence upon the magnitude of the exchange-integral. As shown in Fig. 6, the positive member increases if the orbit-sphere or "shell" radius is small as compared to the size of the lattice (based on the conception of Bahr's model of the atom). This holds true in the case of iron, nickel and cobalt and of a number of rare earths, as indicated, in Fig. 6. Ordinarily the inter-atomic distances in manganese are somewhat too small to permit the ferromagnetic condition. However, its lattice can be expanded by the introduction of other atoms such as those of nitrogen, phosphorus, arsen, antimony, bismuth, sulphur, tin, carbon, or borium, thereby giving a positive value to the exchange-integral and thus creating a ferromagnetic alloy. The ferromagnetism of Heusler's copper, manganese, aluminium and tin alloys can be explained in similar manner.

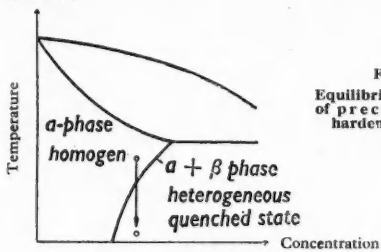


Fig. 7. Equilibrium diagram of precipitation-hardenable alloy.

Proceeding from the finding that certain magnetic phenomena are reversible and others not, alloys with special magnetic properties have been produced in recent years by employing precipitation processes which make it impossible for reversible processes to occur. This process of precipitation-hardening leads to a change in the mechanical, physical, and chemical properties of the alloy. In order to achieve optimum characteristics, a critical state of dispersion of the precipitated constituent is to be aimed at which can be achieved either at room temperature or at elevated temperature. In principle, precipitation hardening can be applied to any alloy which has an equilibrium diagram of the type shown in Fig. 7. Two typical examples are shown in Figs. 8a and 8b (referring to the aluminium-copper and the iron-carbon system respectively).

According to latest concepts three different kinds of precipitation must be distinguished, to wit:

(*a*) Heterogeneous precipitation does not affect the interior of the crystallite, the occurring changes being confined to the grain boundaries where decomposition

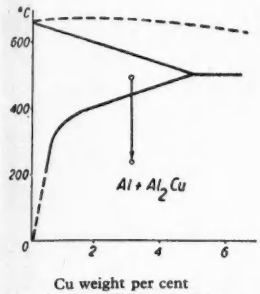


Fig. 8a. Equilibrium diagram of Al—Cu system.

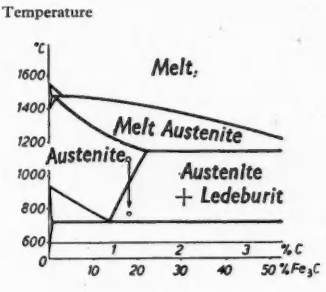


Fig. 8b. Equilibrium diagram of C—F.C. system.

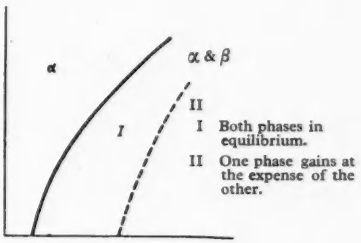


Fig. 8c. Diffusion zones in equilibrium diagram.

of the supersaturated mixed crystal solid solution is accompanied by formation of a fine-crystalline mixture.

(*b*) In homogeneous precipitation the phenomenon has its inception in the interior of the crystallite. There will be little supersaturation if the concentration of one component is small; and under certain conditions differences in concentration may reach a state of balance, as shown in Fig. 8c. Migration of various constituents may serve to enrich one component, thereby creating nuclei for the precipitating phase. Where the differences in concentration have reached a certain limit value, no further balancing is possible.

(*c*) In precipitation without the presence of nuclei, a greater degree of supersaturation exists than in the case of homogeneous precipitation. Thus, if the mixture is halfway between the two balanced phases, either strongly supersaturated *A*-rich mixed crystals may be formed by depletion of the constituent *A*, or *B*-rich mixed crystals may be formed in analogous manner.

While in ferromagnetic alloys the various magnetic properties such as permeability, saturation, coercivity, etc., are of special importance according to the intended use of the alloy, wattage losses in a.c. operation must be as small as possible. These wattage losses are composed of hysteresis and eddy losses, which are differently affected by the structure of the material. The results of an investigation conducted on electrolytic iron specimens are of special interest. As will be seen from Table I, total as well as hysteresis losses are greatly reduced by vacuum anneal at 750 deg. C. The change in structure produced by the anneal is evidenced by Fig. 9, where the original structure of the electrolytically produced iron is seen to be composed of small acicular crystals (Fig. 9). (The dividing line shown in the microphotograph was caused by executing the electrolytical process in two stages.) The multitudinous acicular crystallites are surrounded by individual grain boundaries, both crystallites and boundaries being orientated in the direction of the magnetic flux. By interfering with the continuity of the crystallites, these grain boundaries are responsible for the high hysteresis losses recorded for the unannealed specimen (Table I). As will be seen in Fig. 9b, anneal at 700 deg. C. leads to recrystallisation with an attendant growth of crystallites. However, this temperature did not then suffice to obliterate internal inclusion. But complete recrystallisation was achieved by an anneal at 750 deg. C.,

Table I. Changes in Losses Found with A.C. Magnetization of Electrolytic Iron with Heat Treatment.

Loss factor V_{10} at 50 cycles/sec. in Watt/kg.	As supplied un-annealed	After anneal at 750 deg. C.
Total losses	9.610	2.00
Hysteresis losses	9.457	1.85
Eddy losses	0.153	0.15
Eddy losses in per cent.	1.64	7.34
Induction at 25 amp. turns/cm. ..	15,450	15,400
at 100 „ „ „ ..	18,050	17,600
at 300 „ „ „ ..	20,220	20,200

as shown in Fig. 9c. The considerable decrease in the number of grain boundaries effected by recrystallisation is reflected by a considerable reduction in hysteresis loss, as indicated in Table I. As this table also shows, the assumption that the increased size of the crystallites would cause a rise in eddy loss is not borne out by fact.

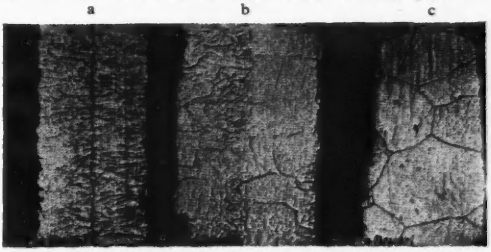


Fig. 9. Microphotographs of structure of electrolytic iron. (a) Left-hand side: original condition. (b) Center: after anneal at 700° C. (c) Right-hand side: after anneal at 750° C.

It is known that the low-loss characteristics of silicon bearing transformer sheet may easily be deteriorated by subsequent manufacturing processes, such as punching. This phenomenon is explained by Fig. 10a, where it is seen that the punching process has pulled the topmost crystallite over the edge of the sheet. This layer-like formation may be assumed to short-circuit the sheet over the entire length of the cut produced thereby augmenting eddy losses. This explanation must, however, rest on the assumption that the individual crystallites were originally isolated from each other by non-conducting, or poorly conducting, grain boundaries. This would justify the assumption that within a certain range of grain size, pure iron crystallites possess low hysteresis loss, and that poorly conducting grain boundaries are conducive to low eddy loss. As will be seen in Fig. 10b, recrystallisation acts in such a way as to interrupt the short circuit, hereby reducing the magnetic losses by five to ten per cent. Since large, pure, and gas-free crystallites with few grain boundaries produce low hysteresis loss, while a fine intercrystalline

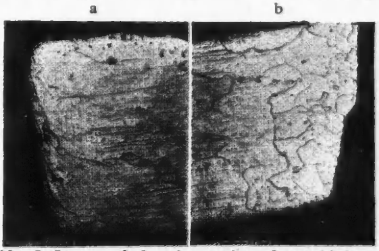


Fig. 10. Influence of sheaving action of punching operation upon structure of silicon sheet.

subdivision of the structure is conducive to low eddy loss, a compromise must be found that will balance these opposing tendencies. But this matter has not been sufficiently investigated as yet.

The phenomenon of recrystallisation under the influence of heat treatment calls for further brief comment. In their nature, recrystallisation and primary crystallisation resemble each other, since nuclei for the propagation of crystallisation is required in either case. The larger the number of these nuclei, the smaller is the space available for individual crystal expansion, and consequently the more fine-grained is the structure. It is a well-known fact that fine-grained structures possess better mechanical properties than coarse-grained ones. The grain boundaries between the crystalline metallic constituents must be destroyed by cold working to such an extent that metallic contact results, thus permitting the building up of new crystallites. Most favourable conditions for recrystallisation will prevail with a certain degree of cold working and with a certain temperature. This interrelationship, which also includes the factors of time and size of grain, is diagrammatically shown in Fig. 11; and it is evident that these various influences must be properly adjusted in their respective effects lest anneal after previous cold working should produce a coarse-grain structure.

The recrystallisation phenomena, observed with aluminium sheet cold worked by twisting the sheet, are illustrated in Fig. 12. Another most interesting case of recrystallisation which had to be thoroughly investigated because of the operational troubles caused by it, is shown in Fig. 13. In this instance, the starting anode of a mercury rectifier was found to shorten in service to such an extent that after a certain time of operation, ignition proved impossible. Investigation revealed that the rod was subjected to recrystallisation under operating conditions, recrystallisation being most pronounced in places where temperature conditions were most favourable to its occurrence. Furthermore, in process of recrystallising, the rod changed from circular to square cross section. This leads to the deduction that the round rod was originally made from a square bar, the process of recrystallisation acting to restore the material to its original shape.

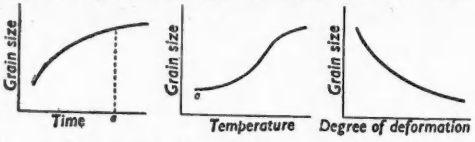


Fig. 11. Grain size versus time, temperature, and degree of deformation.

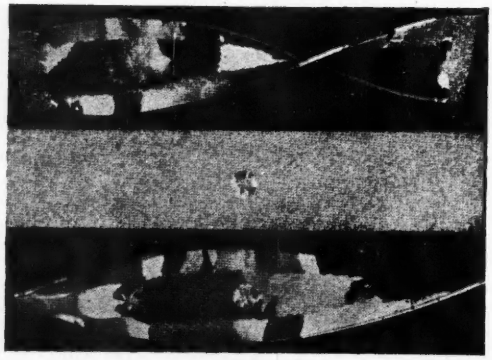


Fig. 12. Recrystallisation of aluminium sheet after cold working by twisting.

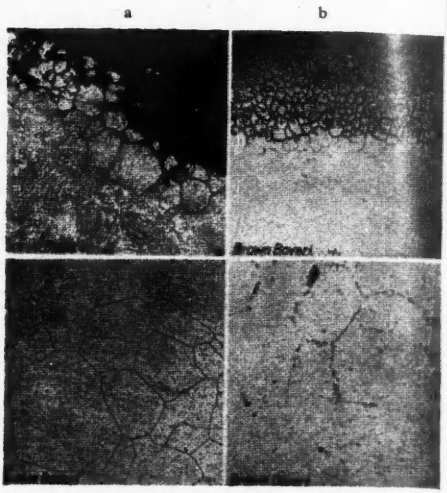


Fig. 14. Corrosion of steel by oxidation:
(a) Carbon steel with oxidation advancing along grain boundaries. (b) 80% Ni, 5% Cr steel, oxidation advancing along grain boundaries. (c) Original structure. (d) Incipient oxidation in grain boundaries.

Similar aspects, to be taken into account when considering certain phenomena occurring in materials, fall into the category of topochemical processes germane to the genetic formation of matter. In this respect, recent investigations have given convincing proof that in the case of local reaction the place at which this reaction occurs is of decisive influence upon the form taken by the products of reaction. Also, considering that the service conditions imposed upon materials are usually of a localised character, it is at once evident that the under-lying genetic conditions must be accurately known if the morphology of the products of reaction is to be properly understood. Vice versa, it may well be possible to draw conclusions from the form in which the reaction products appear upon the conditions under which their formation had been governed. Knowledge

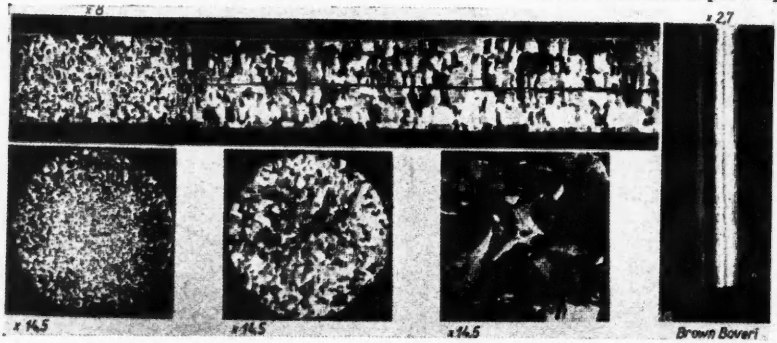


Fig. 13. Recrystallisation of cold-drawn steel rod in service. (Starting anode of mercury rectifier).

upon structure of silicon sheet.

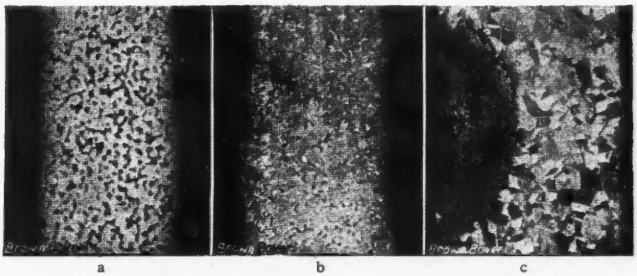


Fig. 15. **Corrosion of Cu—Zn alloys. (Condenser tubing):**

Fig. 15a. α & β structure.

Fig. 15b. Dezincification and attendant plating out of copper.

Fig. 15c. Formation of large copper deposit.

of this kind may prove extremely significant in the explanation of phenomena occurring during operation.

In the organic field it is a well-known fact that a product may vary greatly in its final form according to underlying biological conditions. It appears therefore but logical that the *locus* of reaction should also be included as a factor when considering the principles of genetic formation in the field of the most diversified engineering materials.

As in corrosion the surface constitutes the place of reaction, topochemical aspects are of first-class importance. Examples of the oxidation of metal surfaces at elevated temperatures are shown in Fig. 14. Referring to the microphotograph shown in the upper left-hand corner (Fig. 14a), the progress of oxidation along the grain boundaries of a carbon steel is plainly visible. The way in which oxidation penetrates along the grain boundaries of a Cr-Ni steel into the interior of the metal is illustrated in Fig. 14b, while Fig. 14c shows the same material prior to oxidation, and Fig. 14d shows incipient oxidation along the grain boundaries at considerable depth. Obviously this is a case of strictly localised attack.

In copper-zinc alloys containing crystallites of different phases, corrosion may take a different course. In Fig. 15a is shown the structure of a brass tube, the structure showing α and β phase. The β -phase is removed in the course of time under operating conditions (dezincification), the remaining copper re-precipitating in highly dispersed form (Fig. 15b). Due to the absence of recrystallisation, the metallic cohesion remains interrupted, thereby greatly reducing mechanical strength. Porosity of the structure will, of course, be an attendant feature. In some cases, dezincification and copper re-precipitation may lead to the formation of highly localised places of attack, as shown in Fig. 15c.

Most interesting phenomena occur when mechanically stressed metals and alloys are in contact with liquid metals. Referring to Fig. 16, it is seen from the right-hand side microphotograph that the liquid metal actually enters the material by inter-granular penetration. This penetration-embrittlement may have most disastrous consequences in practice. Thus in one instance it proved impossible to carry out the hot-tinning of a fairly large bronze casting, the penetrating tin in conjunction with existing residual stresses completely disrupting and destroying the casting.

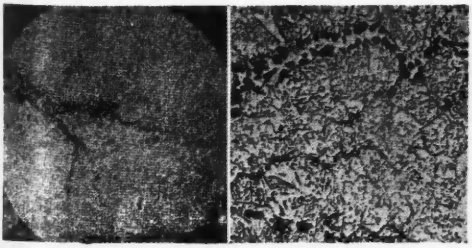


Fig. 16. **Embrittlement by inter-granular penetration of liquid metal.**

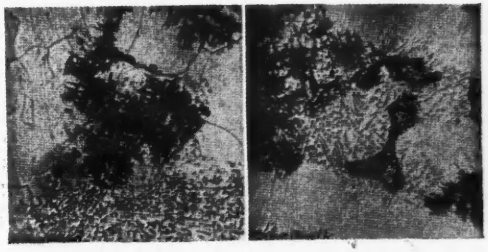


Fig. 17a. Formation of lamellar dendritic inclusions at 600° C.

Fig. 17b. Decomposition of steadite at 650° C., spheroidal formation of temper carbon.

Fig. 17. Formation of temper carbon during growth of cast iron.

The growth of gray cast iron is a phemomenon which has not yet been fully explained. This again is a topochemical process, as demonstrated by Fig. 17. As will be seen from Fig. 17a, temper-carbon has been formed owing to heating at 600 deg. C. for some considerable length of time. This carbon is deposited at the place of reaction in the shape of platelets, all arranged at definite angles and thus giving the appearance of a dendritic structure. As the microphotograph also shows, the pearlite is almost completely decomposed, while the steadite is still preserved and even exerts a stabilising influence upon neighbouring carbite grains. In the vicinity of the steadite, therefore, the pearlite shows relatively greatest resistance to decomposition. However, with an increase to 650 deg C. the steadite also begins to break down. As will be seen in Fig. 17b, the precipitated carbon retains the same configuration as the original crystallite, reproducing its outline and area by dots of non-lamellar carbon particles. In contrast to this, the carbon originating from the decomposition of the pearlite has a rather graphite-like lamellar structure. The special form of the carbon issuing from the decomposition of the steadite may be taken as proof

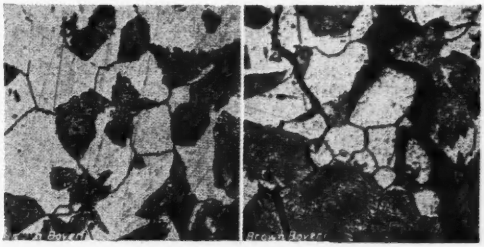


Fig. 18. Corrosion of 18-8 Cr-Ni steel by nitrogen derived from ammonia pyrolysis at high temperature.

that steadite is not a pure ternary phosphide-eutectic, but rather represents a ternary eutectic between phosphide and carbon.

This example serves to show that special investigations into the configurations of certain components of materials make it possible to draw conclusions with regard to their structure, as well as to their properties under working conditions. Structural developments are particularly well shown in Figs. 18a and 18b, in which are seen the micrographs of 18% Cr—8% Ni steel after exposure to an ammonia atmosphere at elevated temperature. Here it is seen that the diffusion of the nitrogeneous gas has led to the formation of fine-lamellar nitrogen-compounds. Ultimate destruction of the material takes place along the grain boundaries, as shown in Fig. 18b.

In earlier times, the properties of metallic working materials were above all determined by the technological process applied to them, as e.g., casting, forging, rolling. Recently attempts have been initiated to influence the properties of the material in such a manner as to diminish the hitherto overriding influence of the production process. Thus, for instance, malleable iron was formerly defined as follows: "Among the cast products of technical iron, malleable iron is mainly employed in cases where rather small pieces of complicated shape and small wall thickness are to be produced which neither can be made of cast-iron because of its brittleness nor can be made as steel castings because of the difficulties connected with casting process, nor even can be made by forging or pressing because of high cost or technical difficulties in general." This description exactly characterises what has just been stated, namely, that it is above all the process of production which characterises the properties of the material. On the basis of the aforementioned definition, the properties of malleable iron are meant to bridge the gap between gray cast-iron castings on the one hand, and steel castings on the other. Until recently, malleable iron filled the position none too well, since it could not be produced with more than 30-40 kg. per sq. mm. tensile strength. For some time past, however, even unalloyed malleable iron of 50-60 kg. per sq. mm. tensile strength could be produced as a matter of routine. Thus the gap between cast-iron and steel castings is narrowed better than heretofore, considering that the lowest tensile strength for which steel castings can be made lies at 40 kg. per sq. mm.

As the formation of temper graphite is a typical topochemical process, its brief discussion may serve well to illustrate the guiding principles of this line of analytical approach. In unalloyed malleable iron the formation of temper graphite serves to create a loosening up of the metallic matrix owing to the creation of temper-graphite colonies. It can therefore be easily understood why, with an otherwise similar structure, malleable iron cannot yield a tensile strength as high as that of steel or of steel castings. But the production has recently been achieved of a high strength malleable iron, the tensile strength and yield point of which hardly differ from that recorded for an equivalent steel; and it has now become possible to produce castings which are completely free of temper graphite and which exhibit completely homogeneous structure throughout the entire cross section of their walls. This has been achieved by an appropriate selection of the constituents of the casting and appropriate heat treatment. Such castings possess tensile strengths of 80-100 kg. per sq. mm. and more, combined with a very high yield point ratio.

The results of tests conducted on materials of this type are charted in Fig. 19 which refers to four different types of heat treatment. Here it is seen that the gap between cast iron and steel castings is now indeed effectively closed.

So far emphasis has been laid upon phenomena and

Strength values versus test bar dia.

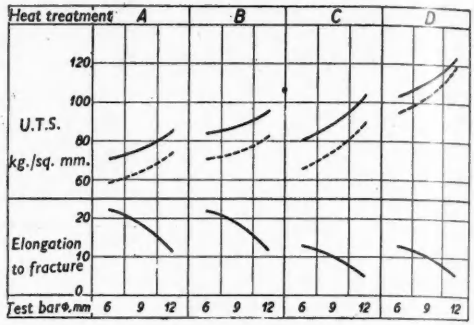


Fig. 19. Influence of heat treatment upon strength of low-alloyed malleable iron.

processes pertaining to metals, that is, to inorganic materials. In order to round off the picture, a few organic materials must also be mentioned. Here, from the viewpoint of engineering materials, particular interest attaches to macro-molecular structures. Between compact and discrete matter there exists a region of gradual transition, beginning with coarse dispersions with particle sizes in excess of 0.1μ and containing more than 10^9 atoms, passing on to colloid dispersions of 0.1μ-1.0μ, with 10^3-10^9 atoms per molecule, and ending with molecular dispersions comprising particle sizes below 1μ with 1-10^3 atoms per molecule. Investigations in the field of macro-molecular chemistry have shown that the organic engineering materials with which this discussion is concerned, belong to the class of colloid dispersions. Of the natural macro-molecular product, cellulose, several derivatives are used in various forms, mainly in electrical engineering for insulation purposes. It is therefore essential that the experts should have a thorough knowledge of these products. The structure of cellulose is characterised by the formula given in Fig. 20. For its use as electrical insulating material, the properties of cellulose with regard to water are of decisive import. When exposed to a humid atmosphere, cellulose attains a state of equilibrium at all degrees of relative humidity. According to the kind of cellulose considered, some 3% to 6% of the water is taken up by absorption, at the exposed hydroxyl groups of the material, as shown in Fig. 21. This is a case of

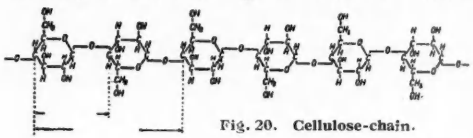


Fig. 20. Cellulose-chain.

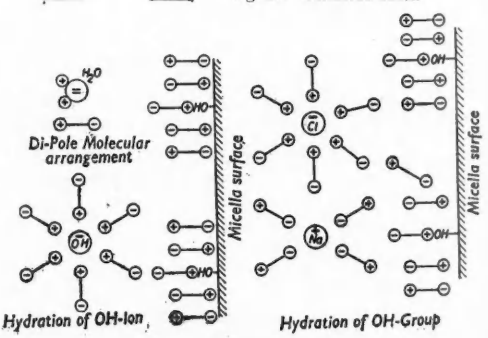


Fig. 21. Hydration of cellulose.

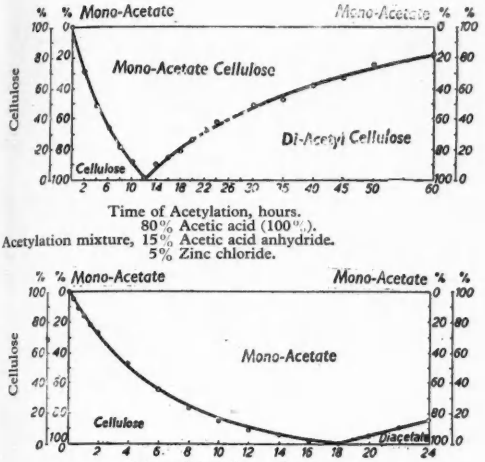


Fig. 22. **Acetylation of cellulose.**

intramicellar absorption; the water suffers a notable contraction and the X-ray spectra of absorbed water are absent. With natural cellulose one molecule of water is absorbed by four glucose groups, which permits the conclusion that one quarter of the glucose groups present in the fibre are located in the micella surface. Additional water, amounting to 20% to 25% of the weight of the cellulose itself, is taken up in the interstitial spaces between the micellae by capillary action. It is this water which is of decisive influence upon the electrical conductivity of the material. Chemical changes affecting the hydroxyl groups can be brought about by acetylation, that is, by producing acetylcellulose. If certain process conditions are adhered to, the fibrous structure will not be affected. The degrees of acetylation which can be attained in this way are given in the diagrams shown in Fig. 22. A treatment of this kind leads to a notable change in properties of the material. Thus, for instance, moisture absorption is considerably reduced, as shown in Fig. 23.

Considering that the electric conductivity depends upon the amount of moisture present, the low-acetylated fibrous cellulose with small moisture content can be expected to possess superior insulating qualities. The correction of this assumption is proven by Fig. 24, which shows the relationship between relative air humidity and the insulating value of this material. Furthermore, it has been found that acetylation effects a decrease in dielectric loss, resulting in a corresponding increase in the insulating level (Fig. 25).

In consideration of the fact that the dielectric properties of the material are adversely affected by the presence of moisture, care must be taken to keep the moisture content of the material as low as possible. In drying the material by suitable means it is, however, essential to prevent excessive drying, as complete desiccation will destroy the mechanical strength. The drying process, therefore, should be confined to the removal of capillary moisture, particularly as the internally adsorbed water does not deteriorate the insulation value. Grave mistakes are still frequently made in the drying of insulating materials composed of cellulose fibre. Thus, for instance, excessive drying temperatures and incorrect timing of vacuum application are a frequent occurrence. The interrelationship existing between oven drying and vacuum drying is exemplified by the special case on which the graph Fig. 26 is based. Here it is seen that irrespective of the drying stage (moisture content) at which it was applied, vacuum drying did not effect a shortening of total drying time.

The various points so far discussed have made it clear that both organic and inorganic engineering materials possess heterogeneous structures. This characteristic must necessarily have its effect upon the macroscopic properties of the materials, such as the mechanical strength. While the kind of reaction originating from the heterogeneity of the structure will be conditioned by the type of mechanical stress-loading applied, the latter loading will in turn be responsible for various phenomena. Therefore, mechanical properties must be judged in full consideration of the type of stressing applied, i.e., whether the stresses are static, cyclic, or of the impact type, and also whether or not the loading is raised up to the occurrence of failure.

Often it will be difficult to establish a specific type of loading in unequivocal manner. Thus the fracturing of crystalline materials under hydrostatic stress could of late only be achieved after much laborious experimentation. Vice versa, with hardened phenoplasts it is not easy to produce deformation by stress prior to fracture. Furthermore, in reference to Fig. 27, it is seen that the appearance of the fracture proper depends upon the conditions under which it is produced. This is likewise proven by the X-ray diffraction photos reproduced in Fig. 28. Here it is seen that with static tensile load, the discrete particles disappear from the diffraction diagram as the straining proceeds and the portions of the crystals are dislocated along the shear planes formed. In contrast to this, in fracture by fatigue (lower part of Fig. 28), the diffraction diagram after fracture still resembles the original diagram—although less pronounced in contour, since the lattice

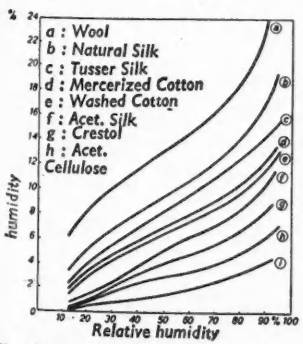


Fig. 23. **Moisture absorption (hygroscopicity) of different fibrous materials vs. relative humidity of air.**

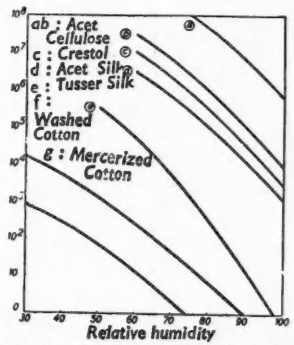


Fig. 24. **Insulation level of fibrous materials as influenced by relative humidity of air.**

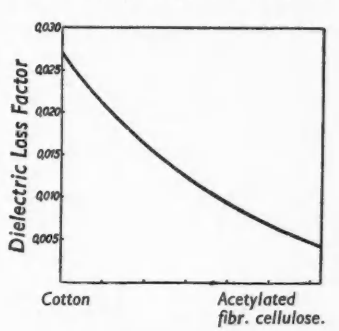


Fig. 25. **Dielective loss factor of cellulose fibre at 1,000,000 cycles per sec. versus degree of acetylation.**

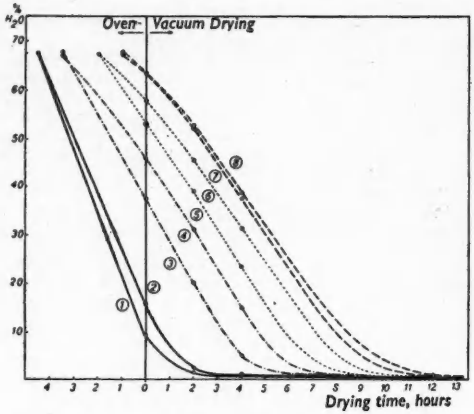


Fig. 26. Drying of cellulose materials, 6 mm. thick. Left-hand side: oven drying. Right-hand side: vacuum drying.

does not undergo plastic deformation in this type of fracture.

In organic fibrous materials such as cotton cellulose, the mechanical properties are governed by the degree of polymerisation and the orientation of the macromolecules in the direction of stress, as indicated in Fig. 29. This diagram also shows that maximum mechanical strength is associated with medium values of polymerisation and not with extreme degrees. In the case of natural silk it has been shown that its main constituent, fibroin, is a non-orientated gel, while pronounced orientation can be ascertained in the thread after spinning. By the solvent treatment of natural silk and subsequent re-spinning the degree of orientation can be increased, hereby improving mechanical strength.

Reference has been made above to the combined stresses imposed upon engineering materials in practice, such as the simultaneous action of temperature and stress in large-scale chemical synthesis. High operating temperatures are also encountered in the field of machine construction, calling for oxidation-resisting and creep-resistant materials. In the case of heat-resisting materials, especial importance therefore attaches to the aspect of heterogeneity of the material, as the amorphous grain boundary and the crystalline grain show different temperature characteristics. Up to a certain temperature limit, the crystallite exhibits a strength inferior to that of the boundary of the grain, while above the equicohesive temperature the position is reversed, as indicated in Fig. 30. Latest investigations have shown the need for an amplification of this

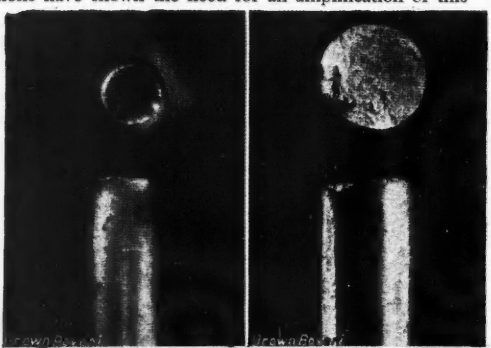


Fig. 27. Different appearance of fracture of steel with tensile and fatigue loading.

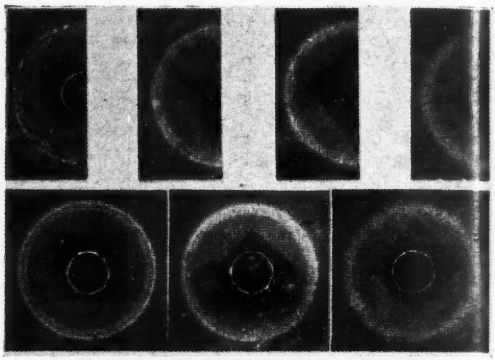


Fig. 28. X-ray diffraction diagrams of fractures. Top: Increasing static tensile load to fracture. Bottom: Cyotic load to fatigue fracture.

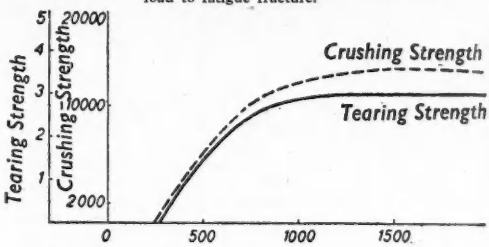
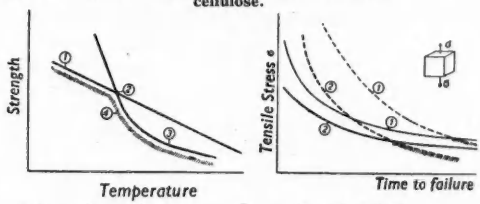


Fig. 29. Degree of polymerisation versus strength of cotton cellulose.



1 Strength of grain
2 Equicohesive temperature
3 Strength of grain boundary
4 Fatigue strength of fracture

—— Boundary rigid
---- Grain rigid
1 Curves for low temperatures
2 Curves for high temperatures
Brittle fractures

Fig. 30. Influence of metallic structure upon fatigue strength.

concept, taking into consideration the relative rigidity of grain and grain boundary. Moreover, the various alloying constituents have different effects upon the temperature characteristics of the material, as evidenced by Table II of long-time tests. Increased high temperature strength and a higher creep limit can be achieved with the use of certain alloying elements which lead to precipitation hardening. Thus, depending

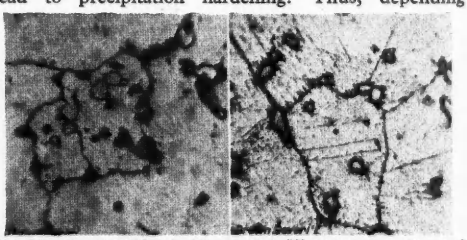


Fig. 31. Precipitation in 29 per cent. Ni 27 per cent. Cr steel with different alloying additions (W, Ti, Ns. Ta.). Left-hand side: original state. Right-hand side: after 48 hours at 650° C. at 20 kg./mm² stress.

TABLE II. LONG-TIME CREEP TESTS WITH VARIOUS STEELS.

No.	Material	Temperature deg.C	C %	Cr %	Ni %	Mo %	W %	Long-time Stress kg./sq.mm.	Creep after 1000 hours %	Estimated creep after 10 years %
1	Carbon Steel	400	0.25	—	—	—	—	22	0.100	0.190
2	Carbon Steel	600	0.25	—	—	—	—	2	0.230	1.320
3	Cr-Mo Structural Steel	400	0.3	0.8	—	0.5	—	60	0.290	1.050
4	Cr-Mo Structural Steel	500	0.3	0.8	—	0.5	—	11	0.230	0.960
5	Mo Steel Casting	500	0.2	+0.2Cu	—	0.4	—	14	0.265	0.960
6	Stainless Cr-Mo Steel	500	0.5	14.7	—	1.2	—	28	0.181	0.700
7	Austenitic Cr-Ni Steel	500	0.11	17.4	8	—	1	35	0.057	0.072

TABLE III. NATURAL TERPENES.

Terpene-Class	Dehydration Products	Main Compounds	Hydration Products	O_2-Derivatives
Hemi-Terpene (Isoprene)	—	C_5H_8	—	—
Mono-Terpene (Ethereal Oils)	$C_{10}H_{14}$	$C_{10}H_{16}$	$C_{10}H_{18}$	Camphor
Sesqui-Terpenes (Balsams)	$C_{15}H_{22}$	$C_{15}H_{24}$	$C_{15}H_{26}$	Resin Acids
Diterpenes (Resins)	$C_{20}H_{28}$	$C_{20}H_{32}$	—	Crocetin
Triterpenes	—	$C_{30}H_{48}$	—	Vitamin A
Tetraterpenes (Carotinoids)	$C_{40}H_{56}$	—	—	Betulin
				Sapogenin
Polyterpenes (Caoutchoucs)	—	$(C_5H_8)_x$	—	Xantophyll

TABLE IV. INFLUENCE OF ROLLING AND TEMPERATURE UPON THE MOLECULAR WEIGHT OF POLYISOBUTYLENE.

Original Molecular Weight	Rolling Temperature deg. C.	Molecular Weight after 30 min. rolling	Molecular Weight after 60 min. rolling
21,500	20	72,000	43,000
	60	123,000	108,000
	100	199,000	169,000
	140	215,000	202,000
	210	180,000	—

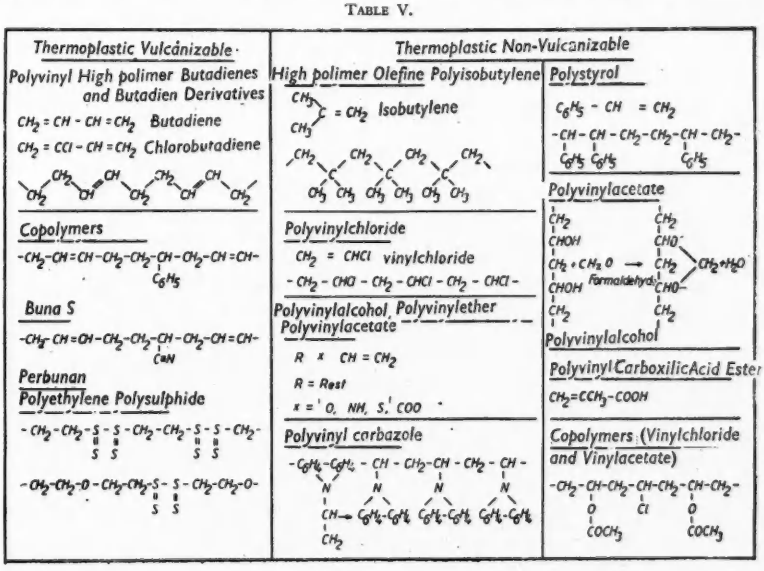
upon the kind of alloy and heat treatment employed, titanium may serve to obtain different creep strength values. Taking the case of titanium steels, the consistent increase in creep strength registered with a progressive increase in titanium content to 2.5 per cent, can be considered as being partly due to the influence of the titanium contained in solution in the α-mixed crystal and partly due to a not fully explored process of precipitation which is very sluggish during anneal and really gets under way only during the creep test.

It is of prime importance to the designer that he should be placed in possession of accurate data concerning the materials to be used in his designs. It will be the task of Standards Associations to disseminate information of this nature ; but standardisation should also comprise the establishing of accurate definitions, particularly with regard to the true nature of the materials under examination. In this respect, the current lack of proper differentiation with regard to the different natures of rubber and caoutchouc is a striking example.

In the field of terpenes, latest chemical research has served to emphasize the ramified relationships between the natural terpenes, their genetic relation being shown in Table III. It should, however, be noted that the biosynthetic formation of caoutchouc latex is not yet fully explained. The caoutchouc constituents are probably formed in the leaves by carbon dioxide assimilation from whence they diffuse to the trunk of the tree, biosynthesis only commencing where latex is already present.

In future. standardisation should, therefore, concern itself with establishing more scientific classifications. Time-honoured mechanistic concepts will have to give way to a more universal point of view. A good example in this respect is the field of synthetic organic materials, where a line should be drawn between partially and fully synthetic products. The former are produced from macro-molecular natural materials by the reduction of these to a state of lower molecularity. This is followed by chemical treatment, subsequent change in chemical structure, and final reconstitution of a macro-molecular compound. In contrast to this, technically produced low-molecular compounds are employed in the production of fully synthetic materials, polymerisation and polycondensation being the two chief processes used. Polymerisation is concerned with the production of thermoplastic materials, which can be

TABLE V.

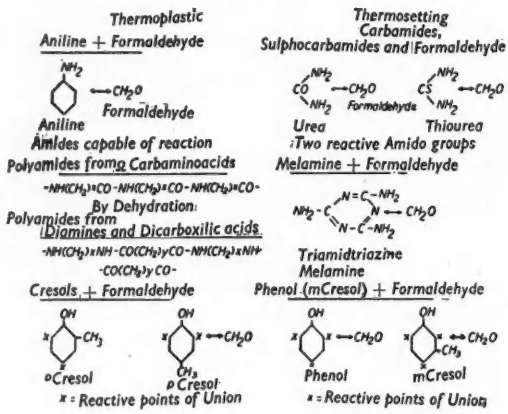


softened by heat and be moulded in any required shape; while polycondensation produces hardenable thermo-setting materials, which are immune to solvents and cannot be molten again.

It has already been mentioned that in the production of partially, as well as of fully, synthetic materials, a reduction in the macro-molecular range is sometimes required. A typical example in this respect is the treatment of polyisobutylene by rolling, the effects of which at different temperatures are given in Table IV. There exists, of course, a lower reduction limit below which reconstitution becomes impossible.

The establishment of a precise classification of synthetic materials has been considered by a technical committee of the Swiss Standards Commission, but definite proposals have not yet been published. From the viewpoint of the consumer of these materials, thermoplastic and thermosetting characteristics are presumably outstanding. For this reason, it has been decided to resort to a classification on the technological basis rather than on the inherently more correct chemical basis. From the technological point of view, the fully synthetic resins can be arranged under the headings of polymers on the one hand and of polycondensation products on the other. As polymers are partly vulcanisable, although not hardenable, this class has been subdivided accordingly in Table V, where the chemical constitution of the various products is also given. The way in which vulcanisation can proceed is likewise indicated. In the case of the condensation products listed in Table VI, a further

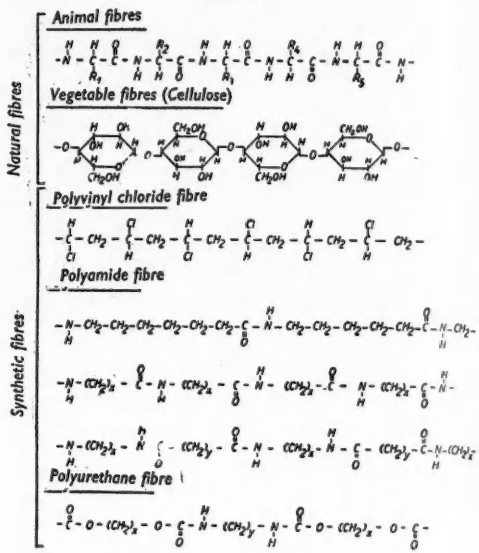
TABLE VI.



subdivision is made according to whether they can be hardened or whether they possess a higher temperature resistance as compared to the thermoplastic polymers, although not being thermosetting in the proper sense of the word. The authors of this classification are, of course, fully aware that this attempt to arrange synthetic resins in a more orderly fashion than heretofore can by no means be considered as the final solution of the problem of classification. Considering the state of flux which at the present time still prevails in the field of synthetic resins, it may yet be well worth while to tolerate a few inaccuracies of definition if this makes it possible to establish data informing the consumer of the most significant differences in the properties of the various products.

It would naturally be greatly preferable to base classification completely upon chemical and physico-chemical foundations, particularly as this leads to interesting comparative data which may well be useful

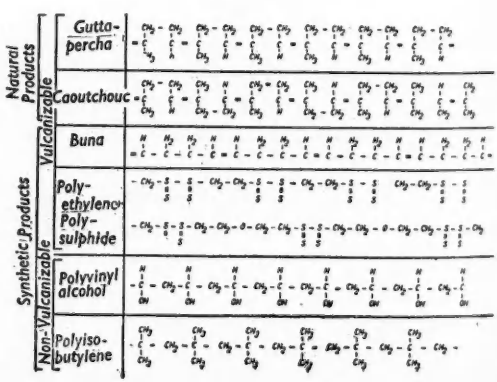
TABLE VII.



also to the consumer. Two classifications based on chemical compositions are given in Tables VII and VIII. It will have to be the scope of further research in the field of macro-molecular materials to find the connecting link between constitution and macroscopic properties. Only then will it be possible to produce materials especially suited to the specific purpose intended. From the larger point of view—as has been indicated above—the task will lie in the further exploration of natural products and in the aforementioned comparative approach to establish the link between natural and synthetic products.

Reference has also been made to the fact that in nature optimum mechanical properties are achieved with medium degrees of polymerisation, at the same time combining mechanical properties with perfection of structure. Engineers and experts on engineering materials will indeed do well to collaborate from this aspect also, in order that technical success may be fully secured.

TABLE VIII.



SOME APPLICATIONS OF THE HEAT PUMP AS A HEATING MACHINE

By A. BAUMANN and D. MARPLES. (From *Brown Boveri Review*, Vol. 30, No. 7/8, July/Aug., 1943, pp. 146-167).

THIS article completes the theoretical explanations, given in THE ENGINEERS' DIGEST, *ante*, by a study of various applications of the heat pump and descriptions of installations. The heating conditions assumed apply primarily to Switzerland, where imported fuel is expensive and exceedingly difficult to obtain.

Whenever heat is required under moderate temperatures—not exceeding the boiling point of water under atmospheric conditions—in the form of hot water or air for heating, washing or drying, as well as for room-heating, the advantages of the heat pump should be carefully examined. The stepping-up process carried out by a heat pump, against an expenditure of high-grade energy, amounts to only a fraction of that necessary to produce the same amount of heat directly, namely, 1/3 to 1/6 for heating plants and 1/10 to 1/20 in evaporating plants with thermo-compressors. Coal tends to become a raw-product rather than a fuel and conservation of energy resources is one of the most urgent problems of the future. From the view-point of national economy the heat pump is, therefore, of interest because it enables fuel to be replaced by inland sources of heat and, as pointed out by Professor Bauer[1], it ensures a more rational consumption of electricity for producing heat.

WHAT CONDITIONS HAVE TO BE FULFILLED BY A HEAT PUMP FOR HEATING?

(a) Either heat from the surroundings or waste heat must be available in sufficient quantities.

(b) The temperature difference between the available source of heat and that required for heating must not be more than 50-80 deg. C.

The conditions (a) and (b) are those necessary to obtain *high coefficients of performance** for the heat pump, as it is only then that it is worth while utilizing heat from the surroundings or waste.

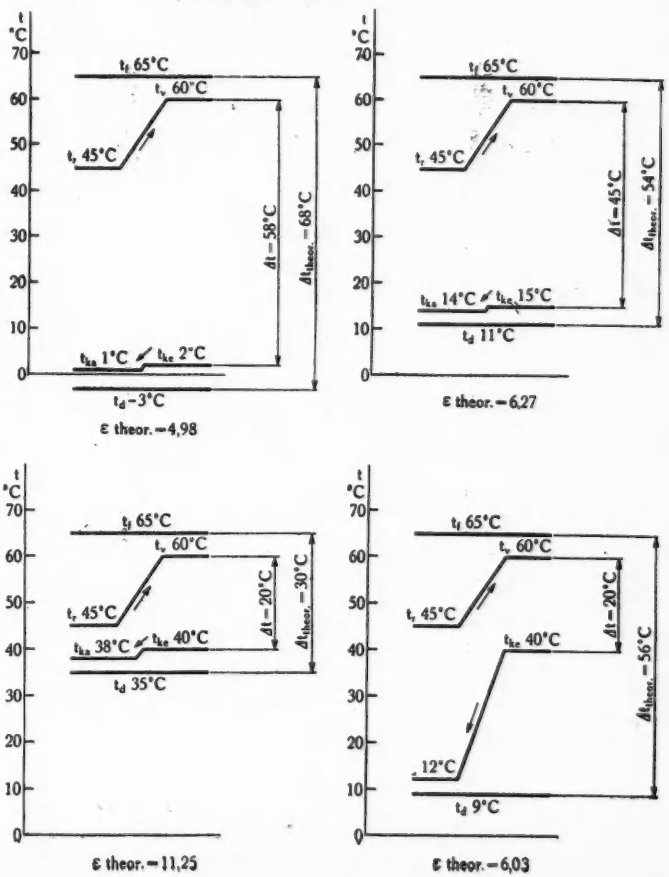
(c) *The heating capacity must be big enough.* According to the present stage of technical development, it should amount to at least 150,000-300,000 kcal/hr†. This applies particularly to auxiliary vapour heat pumps with turbo-compressors.

(d) *The number of operating hours per year and the degree of utilization* of the plant *should be as high as possible.*

1 Prof. Dr. B. Bauer: "Die Wärmepumpenanlage Walcheplatz in Zürich," Technical Supplement, No. 406 of the *Neue Zürcher Zeitung*, March 10th, 1943.

* See A. Meldahl: "The Heat Pump as Refrigerating and Heating Machine," *Engineers' Digest*, Vol. 5, No. 5.

† 1 BThU = 0.252 kcal.



Figs. 1-4. **Temperature diagrams for heating water from 45 deg. to 60 deg. C. for four different conditions of the source of heat.**

Figs. 1 and 2. The source of heat consists of river water at 2 deg. C. during winter (Fig. 1) and 15 deg. C. during summer (Fig. 2). As an ample amount of river water is available, it follows that its temperature drop across the evaporator (t_{ke}-t_{ka}) is small, which ensures a comparatively high performance of coefficient ε.

Figs. 3 and 4.

Fig. 3 shows the conditions when waste water at 40 deg. C. is available in ample quantity, whereas in Fig. 4 it is limited. Despite the high temperature of the source of heat, high performance coefficients ε can be obtained only if waste water is available in sufficient quantity (Fig. 3), otherwise its temperature drop across the evaporator can become so great that the performance coefficient is no higher than if the evaporator is heated with 15 deg. C. river water (Figs. 4 and 2).

Among the conditions necessary to obtain a high performance coefficient for the heat pump it is necessary to ensure an ample supply for the source of heat.

t_v	Temperature of hot water leaving condenser (60 deg. C. for all cases).
t_r	Temperature of hot water returning to condenser (45 deg. C. for all cases).
t_{ke} and t_{ka}	Temperatures of the source of heat when entering and leaving evaporator.
Δt	Temperature difference between hot water leaving condenser and source of heat entering evaporator.
t_f	Liquefaction temperature of auxiliary vapour in condenser.
t_d	Evaporation boiling temperature of auxiliary vapour in evaporator.
Δt theor.	Temperature difference (t_f-t_d).
ε theor.	Performance coefficient, defined as follows :—

$$\frac{273 + t_f}{(273 + t_f) - (273 + t_d)} = \frac{(273 + t_f)}{\Delta t_{\text{theor.}}}$$

(e) If an electric drive comes into consideration—which is mostly the case—*the necessary electrical energy must be available at a reasonable price.*

Sources of heat and coefficient of performance.

Practically unlimited sources of heat are constituted by water from rivers and lakes ; ground water ; air from rooms and by warm cooling water from machines. The influence of the magnitude of the source of heat is shown (Figs. 1-4), a comparison between Figs. 3 and 4 being particularly instructive.

Whenever water from the surroundings is taken as a source of heat, the heat-pump plants have to be located in their vicinity to keep down the costs of pumping. As a norm for the quantity of water required, it can be stated that *one cu. m. of water per second flowing through the evaporator corresponds an hourly heating output of about 4.5 million kcal.*, it being assumed that the lowest temperature of the source of heat during the winter amounts to 2 deg. C. and that the hot water leaves at a temperature of 60 to 70 deg. C.

The effective coefficient of performance ϵ_{kl} refers to the power input at the motor terminals and can be written as follows :

$$\epsilon_{kl} = \frac{Q}{AL} = \frac{T_v}{T_v - T_{ke}} \cdot \eta = \frac{T_v}{\Delta t} \cdot \eta \text{ where}$$

Q designates the heating output in kcal./hr.

AL the thermal equivalent in kcal./hr. of the electrical energy expended by the driving motor.

T_v leaving temperature to heating system in deg. K.

T_{ke} temperature of the source of heat in deg. K. (e.g., river water).

Δt the difference between the two aforementioned temperatures.

η the overall efficiency of the installation due to the various losses, including the irreversibility of the heat-pump cycle.

For auxiliary-vapour heat pumps with turbo-compressors, the overall efficiency varies approximately as follows :

Heating output of the unit kcal./hr.	Overall efficiency η
200,000–1,000,000	0.45–0.55
1,000,000–3,000,000	0.55–0.60
over 3,000,000	0.60–0.65

The following performance coefficients are influenced by the temperature differences mentioned.

Application.	Performance coefficient referred to motor terminals
1. *Room heating* with standard radiators 90/70 deg. C., leaving temperature from heat pump 65 deg. C.	2.5–4
2. *Room heating* with radiators for 45 deg. C. leaving temperature from heat pump, heating by radiation or from ceilings	3.5–6
3. Heating hot water to 70 deg. C. for industrial purposes :	
(a) with water from surroundings	2.5–4.0
(b) with warm waste water ..	3.0–7.5
4. *Swimming pools.* Leaving temperatures from heat pump 40 deg. C.	
during winter	4.0–6.0
during summer	6.0–8.0
5. *Air heating.* Leaving temperature from heat pump 30 deg. C.	
(a) with closed circuit	2.5–6.0
(b) with fresh air and ground water	8–12
6. *Evaporating plants* with thermo-compressor	
for solutions boiling with difficulty	5–10
for solutions boiling readily ..	11–25

Power input.

The foregoing figures enable the approximate electrical power input and motor rating to be easily determined, as can be seen from the following example :

For a case according to 2, the heating output amounts to 3.0 million kcal./hr. and the coefficient of performance to 4.5. The power input at the motor terminals is therefore :

$$L = \frac{3{,}000{,}000}{4.5 \times 860} = 775\ kW$$

i.e., 4.5 times smaller than with direct electric heating.

Influence of heating output per heat-pump unit.

An increase in output per unit ensures lower installation costs and also a more favourable overall efficiency. In the case of an auxiliary vapour machine with turbo-compressor the lower limit of output, per unit, is between 300,000 and 150,000 kcal./hr., depending on the temperature of the source of heat. According to Bauer and Peter[2] the room heating output amounts to 17 to 22 kcal./hr. per cu. m. of enclosed volume for climatic conditions in North and East Switzerland, regardless of wind and radiation influences, the outdoor temperature being –20 deg. C. and room temperature 18 deg. C. Therefore, the smallest built-in volume of buildings that can be heated by a heat-pump lies between 7000/17,000 cu. m., according to conditions.

Load factor and number of full-load operating hours.

As with any other machine, these factors have in the present case an appreciable influence on the cost of the heat produced. They can be defined as follows :—

Load factor of the heating machine :

$$\alpha = \frac{\text{amount of heat effectively produced per year (kcal.)}}{\text{maximum amount of heat that can be produced per year (kcal.)}}$$

Number of full-load operating hours :

$$h_{fl} = \frac{\text{amount of heat effectively produced per year (kcal.)}}{\text{hourly full load heating output (kcal./hr.)}}$$

The cost of producing heat becomes smaller as the number of hours per year during which the machine is running fully loaded is increased. Industrial processes requiring large amounts of heat and operating continuously naturally give the most favourable results. The conditions for room heating are given in Table I.

INDUSTRIAL APPLICATIONS OF HEATING MACHINES.

Suitable conditions for industrial application occur in the textile industry, in paper and chemical works, breweries, laundries and tanneries. Drying processes lend themselves particularly well to the heat pump, especially when use can be made of any waste heat.

An example of an industrial heat-pump plant for producing hot water at 70 deg. C. from lake water, which varies between 3 deg. C. in the winter and 13-20 deg. C. in the summer, is installed at Steckborn Artificial Silk Co. Ltd., Switzerland. This plant comprises two thermoblocs, each for 1.0 to 1.7 million kcal./hr., and with one unit alone in operation, approximately 2,100 tons of coal are saved annually. The intake of water from Lake Constance is at a certain distance from the shore and is arranged so that the water is taken in at the highest temperature possible, i.e., on the surface in summer and from a deeper level in winter. Each thermobloc consists of a turbo-compressor, driven by an

2 B. Bauer and W. Peter : " Wasser und Energiewirtschaft," Nos. 7/8, 1935, p. 109.

TABLE I.

NUMERICAL EXAMPLE OF COMBINED ROOM HEATING WITH A HEAT PUMP AND FUEL, FOR A RATED HEATING CAPACITY OF 6 MILLION KCAL/HR.

(a) Heat pump

Percentage of the rated heating capacity furnished by the heat pump	Rated heating capacity of heat pump Million kcal/hr.	Daily heat output of the heat pump with −20° C. outdoor temperature Million kcal/hr.	Percentage of annual heat consumption furnished by heat pump	Number of full-load operating hours of heat pump hr. approx.	Warming up The heat pump alone is sufficient for outdoor temperatures not lower than deg. C. approx.	Normal operation deg. C. approx.
50	3.0	72.0	99.0	2060	—1.7	—10.5
40	2.4	57.6	97.5	2520	+1.2	— 5.3
30	1.8	43.2	92.0	3200	+4.0	— 0.6

(b) Heating with fuel alone

Total amount of heat necessary with outdoor temperature t_a = — 20 deg. C.	Total amount of heat required when t_a = —20 deg. C.	Load factor referred to an operating period of 225 days	Number of full-load operating hours when heating with fuel alone
Warming up 6 million kcal/hr. Normal operation 4 million kcal/hr.	102 Million kcal	28 per cent	about 1030

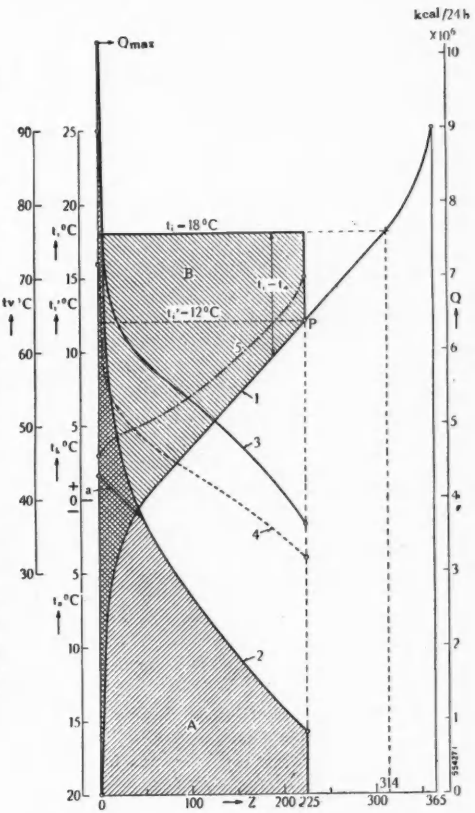


Fig. 5. **Example showing the determination of the amount of heat required for room heating and the choice of the base load for the heat pump. (For climatic conditions at Zurich).**

Abscissae : Z. Number of days per year.

Ordinates :

t_a Mean daily outdoor temperature.

t_k Temperature of the source of heat (water from the River Limmat)

t_i Room temperature (18 deg. C.) to be maintained by heating.

t_i' Heating limit (12 deg. C)., i.e., mean outdoor temperature above which heating is stopped.

t_v Heating water leaving temperature.

Q Daily heat consumption in kcal deduced from frequency (curve 1) of mean outdoor temperatures.

Q_{max} Maximum demand for heat in kcal per 24 hours when t_a = — 20 deg. C.

Curve 1. Frequency curve of the mean daily outdoor temperatures in the town of Zurich, according to records of the Swiss Central Meterological Institute between 1869 and 1929. Point P, for instance, implies that in Zurich during the last 60 years, there were on the average 225 days per year with a mean daily outdoor temperature not exceeding 12 deg. C.

Curve 2. Frequency curve of the daily demand for heat Q, as deduced from curve 1 : $Q = f(t_i - t_a)$.

Curve 3. Frequency curve of the leaving temperature t_v of heating water when heating up.

Curve 4. Ditto, for normal operation.

Curve 5. Frequency curve of the temperature t_k of the source of heat.

Surface A. Mean heat consumption in kcal during the entire heating period of 225 days.

Surface B. Mean degree-day surface during the heating period. Each degree Centigrade difference ($t_i - t_a$) per day, gives one degree-day. If on a given day the difference $t_i - t_a$ = 6 deg. C., this day reckons as six degree-days. (Cf. Hottinger, " Klima und Gradtage," Publishers, J. Springer, Berlin, 1938).

If the heat pump is dimensioned for a base load equal to 30 per cent of the installed heating capacity, the amount of heat it produces is limited approximately by line a in the surface A. It can cover approximately 92 per cent. of the total yearly demand for heat, only the small amount corresponding to the peaks above line a having to be furnished by additional means.

Fig. 6 shows the conditions for other values of the base load.

8000 V induction motor via gearing, an evaporator and a condenser. Methylene chloride (CH_2 Cl_2) has been adopted as the working medium.

Another interesting installation is at the Landquart Paper Mills, Switzerland ; here, the heat pump operates with *air* and not with an auxiliary medium. This plant is designed for a heating output of 115,000 kcal./hr. The compression and expansion is carried out by means

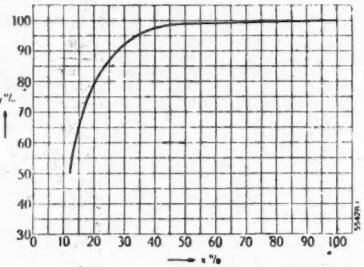


Fig. 6. Percentage of the total amount of heat consumed per year furnished by a heat pump dimensioned for varying percentages of the total installed heating capacity, the heating conditions being as assumed in Table I.

Abscissae : Heating capacity of heat pump X as a percentage of the maximum output of the installation.

Ordinates : Percentage Y of the total yearly consumption of heat furnished by the heat pump.

Heat pumps for room heating have to be dimensioned for the base load. 90 per cent of the total heat consumption can be covered by a heat pump dimensioned for approximately 30 per cent. of the maximum heating capacity of the plant.

of a cellular rotor system. Moist, warm air from the paper machines serves as the source of heat. The heat pump receives air, already heated to 30 deg. C. in recuperators, and raises its temperature to 40 deg. C. before use for drying felts in the paper machine. This relatively small plant effects a saving of approximately 180 tons of coal per year.

HEAT PUMP FOR ROOM HEATING.

Fig. 5 shows the determination of the amount of heat required for room heating and the choice of the base load for the heat pump. As a general rule, heat

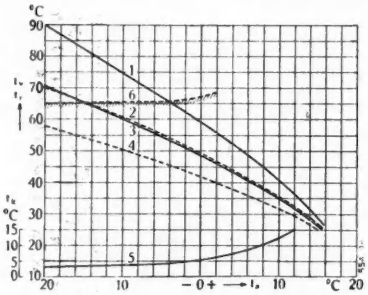


Fig. 7. Leaving and return temperatures of hot water for standard radiators in function of the outdoor temperature, showing how they can be adapted to operation with a heat pump.

t_a Outdoor temperature.
t_k Temperature of source of heat.
t_v Hot-water leaving temperature.
t_r Hot-water return temperature.

1 = t_v, 2 = t_r } Temperatures for standard radiators when heating up.

3 = t_v, 4 = t_r } Temperatures for normal operation.

5 = t_k Temperature of the source of heat in function of the outdoor temperature.

6. Leaving temperatures which can be reached by the heat pump when the temperature of the source of heat t_k varies.

In order to keep the performance coefficient of the heat pump as high as possible and reduce the amount of energy consumed, the leaving temperature of the heat pump should not appreciably exceed 65 deg. C. By increasing the surface of the radiators, the heat pump can meet the demands beyond curve 6.

pumps for room heating are dimensioned for a given base load, whereas the peaks are covered with the aid of less expensive heat producers, such as boilers or electricity. Fig. 6 shows to what extent the total heat consumption can be covered by the heat pump when it is dimensioned for varying percentages of the installed heating capacity. The value of the leaving temperature is of decisive importance for the economy of the heat pump. Fig. 7 shows, as a function of the average outdoor temperatures, the leaving and return temperatures for standard hot-water radiators, designed for 90 deg. C. leaving and 70 deg. C. return temperatures when the outdoor temperature is –20 deg. C. both for normal heating and when heated up.

THE HEAT PUMP IN CENTRAL HEATING PLANTS.

Centralized production of heat offers many advantages over heating from a number of small scattered plants, and burning fuel for producing heating steam at relatively low pressures and temperatures for maintaining rooms at 18 deg. C., for instance, represent unwarrantable squandering of energy. Is it not a mistake to consume fuel for producing electrical energy which is then employed for driving a heat pump for heating rather than use the fuel directly for heating ? The heat-flow diagrams (Figs. 8-11) show the percentage of useful heat obtainable from 100 heat units of fuel burnt for other kinds of heating and combined heating and power plants. The most interesting example is afforded by the utilization of all the available steam for driving the heat pump by means of a steam turbine (Fig. 11[3]).

For a given heating output, the fuel consumption in the arrangement is only 55-60 per cent. of that of a low-pressure heating plant. Similar advantages accrue from an electric drive instead of a steam turbine as in Fig. 11, whenever it is not possible to mount the turbine and heat pump together. Figs. 12-13 show the central heating and power installation at the Swiss Federal Institute of Technology, Zurich, which supplies the needs of 17 buildings in the establishment, 37 buildings in the Cantonal Hospital, 3 large buildings in the Cantonal Administration, and 85 private buildings.

THE HEAT PUMP FOR HEATING AND COOLING IN AIR-CONDITIONING PLANTS.

Air-conditioning plants require appliances for heating and cooling ; these can both be met by a heat pump. The installation at the Congress Building at Zurich has an output of 50,000 kcal./hr. when heating and 27,000 kcal./hr. when cooling.

The main object of air conditioning in industrial plants is to maintain the most favourable conditions for the workers and maximum output, and particularly to improve the quality of the products. Gear cutting in our works, for example, is carried out in a shop where the air is conditioned, and into which no daylight can penetrate, because it is only in this way that the requisite accuracy can be obtained. Similar conditions exist in plants manufacturing precision optical and measuring instruments.

Fig. 14 shows a projected installation for an optical-instrument works.

The room temperature has to be maintained constantly at 22 deg. C. throughout the year, which implies, on the average, heating for 300 days and cooling for 65 days per year. The amount of fresh air taken in is only

3 This arrangement was already mentioned by Lord Kelvin in 1852, and proposed in its present form by Professor B. Bauer, Director of the centralized heating plant of the Swiss Federal Institute of Technology, Zurich.

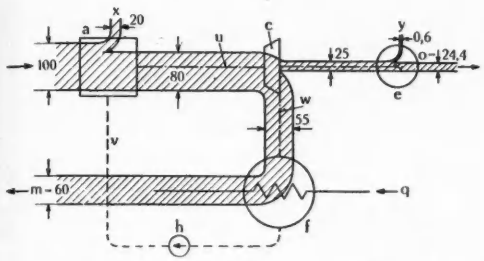


Fig. 8. **Power station with condensing steam turbines in a large city, the energy of which is used in the first place for electric heating* (hot water and steam boilers, radiators, cooking, &c.).**

Of 100 kcal introduced as fuel only 24.4 kcal are available in the form of useful energy, which is, however, of very high grade, whereas the greater part is carried away by the cooling water.

*The comparison between the four examples considered is evidently only valid on condition that all energy (high and low grade) produced is used for the same purpose, viz., heating.

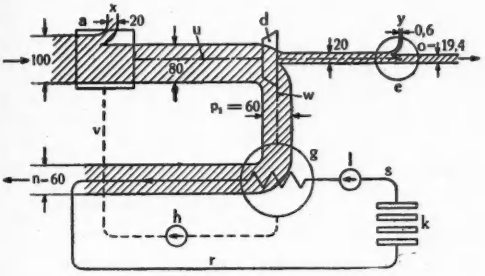


Fig. 10. **Centralized heating power station.**

The arrangement differs from Fig. 8 in that the exhaust steam from the turbine is not led into an ordinary condenser, but into a heating condenser under a correspondingly higher pressure, where it gives up heat to hot water from the heating plant.

Of 100 kcal introduced as fuel, 19.4 are converted into high-grade energy by the generator, whereas 60 are given up by the heating condenser for heating, so that altogether 79.4 are utilized.

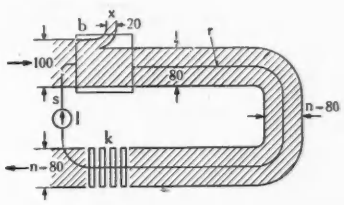


Fig. 9. **Low pressure heating plant (central heating).** Of 100 kcal introduced as fuel, 80 can be used for heating).

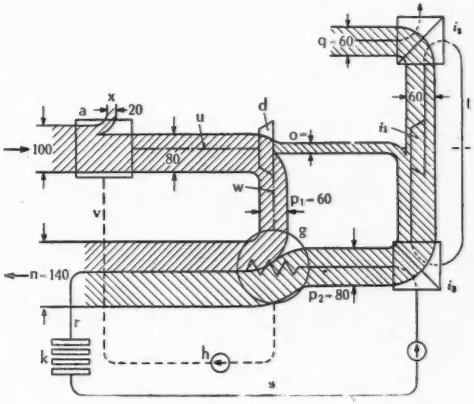


Fig. 11. **Heat pump with steam-turbine drive in a centralized heating station.**

The mechanical energy, equivalent to 20 kcal, produced by the turbine d is employed directly for driving the heat pump. If the latter has a performance coefficient of 4, it will deliver 80 kcal for heating, whereas a further 60 kcal are supplied by the heating condenser, as in Fig. 10. Hence, an amount of heat for heating of 140 kcal can be obtained from 100 fuel kcal.

Figs. 8-11. **Heat flow diagrams for different kinds of heating, showing the ratio between the amount of heat available for heating and that of the fuel consumed.**

The most advantageous results are again obtained with the aid of a heat pump (Fig. 11); from 100 kcal contained in the fuel, 140 kcal can be made available for heating; in other words, 100 kcal for heating require an expenditure of fuel corresponding to only 70 kcal, whereas the remaining heat is taken from the surroundings. These results are interesting inasmuch as they show how large amounts of fuel can be saved whenever considerable quantities of heat are required by the addition of a heat pump.

a High-pressure boiler.
b Hot-water heater.
c Condensing steam turbine.
d Heating turbine.
e Generator.
f Normal condenser, cooled by river water.
g Heating condenser, cooled by hot water.
h Feed pump.
i_1 Compressor driven by heating turbine d } of the heat pump (heating machine)
i_2 Evaporator. }
i_3 Condenser. }
k Heaters.
l Hot-water circulating pump.
m Heat carried away (lost) by cooling water.
n Useful heat.
o Thermal equivalent of energy consumed.
p_1 Useful heat from heating condenser.
p_2 Useful heat from heat pump.
q Cooling water, i.e., source of heat in Fig. 11.
r Leaving hot-water.
s Returning hot-water.
t Working-medium circuit of heat pump.
u Live steam.
v Feed water.
w Exhaust steam.
x Boiler losses.
y Generator losses.

sufficient for its renewal. Part of the air coming from the rooms is re-utilized, and is mixed with the fresh air, thus going through a partly-closed circuit. This arrangement offers the advantage of reducing the temperature drop between incoming and outgoing air, and thus ensuring a more even distribution of heat. It may be recalled at this juncture that the smaller the temperature difference which has to be surmounted by the heat pump, the greater becomes its performance coefficient and therefore its efficiency.

The automatic regulation of the state of the air calls for continuous adjustment of the amount of heat furnished or removed by the air-conditioning plant, as well as of the humidity content of the air. Such a plant requires, therefore, very comprehensive devices for circulating the air (ventilation), drying, dehumidifying and precipitating fog, as well as humidifying, elimination of harmful gases or dust, cooling and heating, the control of which calls for carefully-studied regulation. The choice of the means adopted for heating, cooling, etc., depends on the process considered and on the degree of accuracy within which the conditions have to be maintained (base load or exact heating, cooling, etc.). They can also vary from summer to winter.

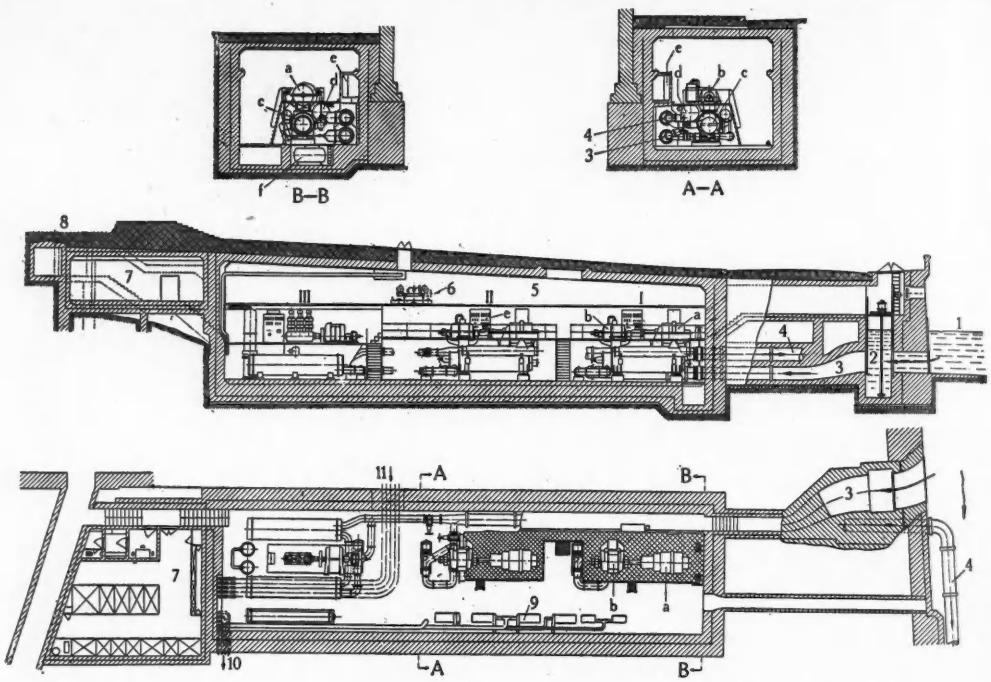


Fig. 12. **Subterranean heat pump station of the centralized heating and power plant of the Swiss Federal Institute of Technology, Zurich.**

I, II. Brown Boveri thermoblocs. III. Third heat pump unit with reciprocating compressor.

1 River Limmat (source of heat)
2 Water intake
3 Intake pipeline
4 Water outlet pipeline
5 Machine room with heat pumps I, II and III.
6 Machine-room crane
7 High-tension room
8 Entrance
9 Hot-water circulating pumps
10 Leaving pipelines for hot water
11 Return pipelines for hot water

a Turbo-compressor b Driving motor c Evaporator d Condenser e Switchboard f Freon-11 container

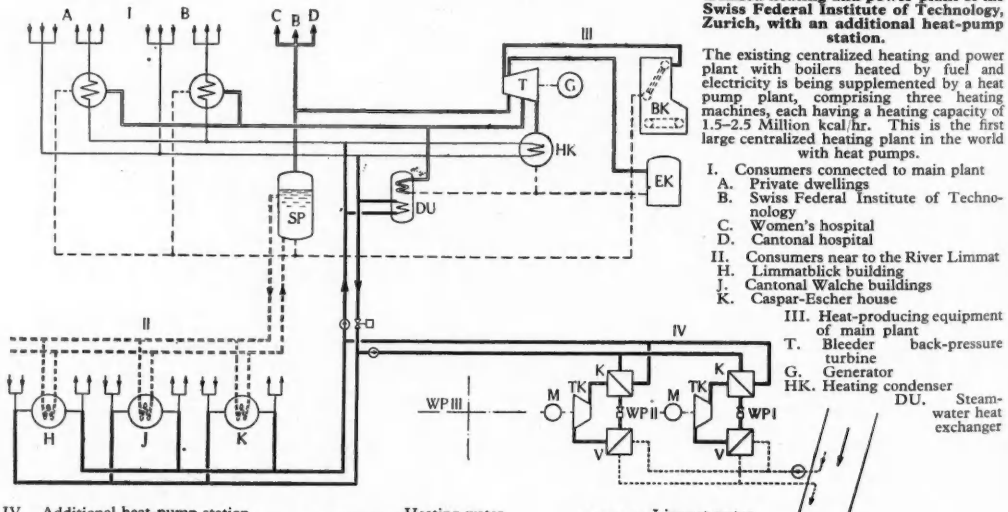
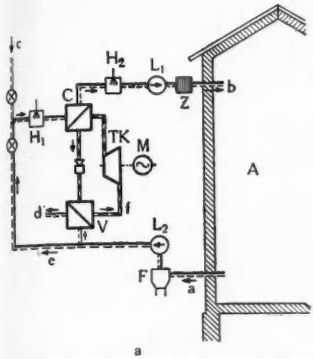


Fig. 13. **Layout diagram of the centralized heating and power plant of the Swiss Federal Institute of Technology, Zurich, with an additional heat-pump station.**

The existing centralized heating and power plant with boilers heated by fuel and electricity is being supplemented by a heat pump plant, comprising three heating machines, each having a heating capacity of 1.5–2.5 Million kcal/hr. This is the first large centralized heating plant in the world with heat pumps.

I. Consumers connected to main plant
A. Private dwellings
B. Swiss Federal Institute of Technology
C. Women's hospital
D. Cantonal hospital
II. Consumers near to the River Limmat
H. Limmatblick building
J. Cantonal Walche buildings
K. Caspar-Escher house
III. Heat-producing equipment of main plant
T. Bleeder back-pressure turbine
G. Generator
HK. Heating condenser
DU. Steam-water heat exchanger
IV. Additional heat-pump station.
WP I, WP II, WP III. Heat pump sets
V. Evaporator K. Condenser
TK. Turbo-compressor M. Motor
SP. Heat accumulator
BK. Fuel-fired boiler
EK. Electric boiler

Heating water
Circuit of working medium of heat pump
Steam
High-pressure heating water for covering largest load peaks
Condensate
Limmat water
Heating water



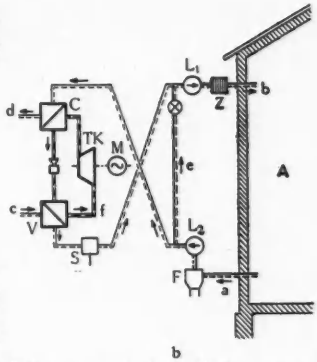
a

Winter connection with heat pump as heating machine

Figs. 14 a and b. Projected heat pump installation for an optical-instrument factory

Conditioning air in workshops increases the output and accuracy, i.e., quality of the manufactured products.

A. Closed workshops
M. Driving motor
TK. Turbo-compressor
V. Evaporator
} of the heat pump
C. Condenser
L_1. Fresh-air fan
L_2. Exhaust-air fan
D. Dust filter
W. Water separator
H_1, H_2. Humidifiers
Z. Additional heating
a Outlet duct for exhaust air
b Inlet duct for conditioned fresh air
c Intake of fresh, outdoor air
d Part of exhaust air returned to the atmosphere
e Air going through a closed circuit, which is mixed with the fresh, outdoor air
Working-medium circuit of the heat pump



b

Summer connection with heat pump as cooling machine

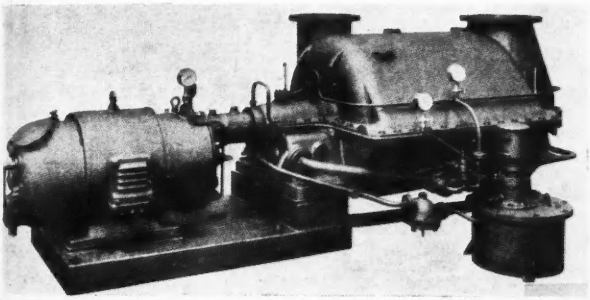


Fig. 15. **Thermo-compressor for handling a mixture of alcohol and water vapour (vapour pressure exchanger).**

Weight of vapour handled	400 kg/hr.
Suction pressure	0.0204 kg/cm² abs.
Delivery pressure	0.102 kg/cm² abs.

EVAPORATING PLANTS WITH HEAT PUMPS.

Very great possibilities for utilizing heat pumps (thermo-compressors) exist in evaporating plants; in the chemical industry for manufacturing pharmaceutical products, concentrating dyes, evaporating solutions; in the preparation of foodstuffs such as concentrated fruit juices, powdered and condensed milk, and for preparing table salt and sugar. It is also possible to obtain drinking water from sea or other water unfit for consumption, by distillation with the aid of a thermo-compressor. Conditions in these plants are much more favourable for heat pumps than for heating installations. Temperature differences are small, thus ensuring high performance coefficients. Furthermore, the plants themselves are simple and inexpensive, and the working costs are but a fraction of those necessary to obtain the same results by heating with live steam. The evaporation of solution calls for the heat expenditure of 550/600 kcal. per kg. of water evaporated and can be effected in a simple manner with a thermo-compressor which operates with high efficiency, since a consumption of energy of one kWhr. permits the evaporation of 10-35 kg. of water according to the operating pressure, nature, and concentration of the substance treated.

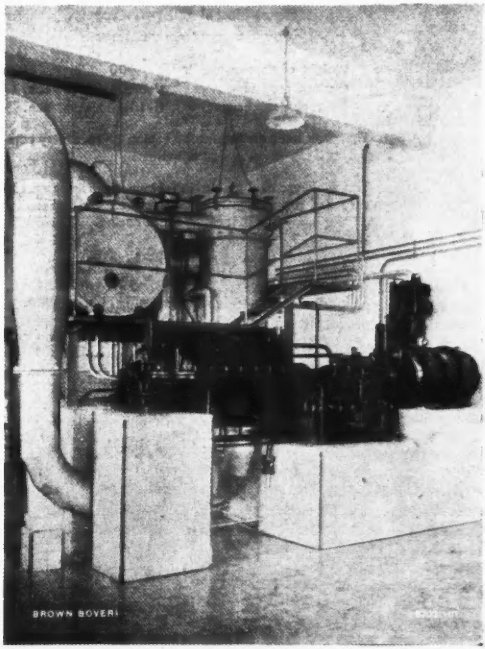
Fig. 16. **Thermo-compressor in an evaporating plant handling milk products.**

Nominal evaporative capacity: 1000 kg. of water per hour.

Evaporation with thermo-compressors affords an ideal means of concentrating liquid foodstuffs. Among the many advantages they posses, may be mentioned: (a) Concentration can be carried out at the moderate temperatures necessary for conserving vitamins, the flavour and aroma; (b) The various operations are carried out with maximum cleanliness and hygiene due to the use of electricity and the suppression of fuel.

The ratio $\lambda = \frac{G}{L}$ is called specific evaporation figures, G being the amount of water evaporated in kg. per hour and L the power input measured at the terminals of the motor driving the thermo-compressor.

Both performance coefficient ϵ and specific evaporation figure become higher as the temperature level—i.e., the operating pressure—is raised and the temperature difference Δt between the saturation temperatures corresponding to the pressures at the outlet and inlet of the thermo-compressor become small.



Example showing the influence of the pressure level.

Weight of water to be evaporated 1000 kg./hr. Boiling temperature of the solution of $t_o = 45$ deg. C., $T_o = 318$ deg. K and a temperature difference $\Delta t = 14$ deg. C., hence $t_1 = 59$ deg. C. and $T_1 = 332$ deg. K. With the given size of plant, an overall efficiency of $\eta = 0.55$ can be assumed.

The performance coefficient amounts to

$$\epsilon = \frac{332}{14} \times 0.55 = 13.05$$

The power input at the motor terminals can be determined from this figure as being equal to 58 kW. Hence :

$$\lambda = \frac{1000}{58} = 17.2 \text{ kg./kWhr.}$$

If, on the other hand, evaporation is carried out under atmospheric pressure, i.e., $t_o = 99$ deg. C., $T_o = 372$ deg. K, and all other conditions remaining the same, so that $t_1 = 113$ deg., $T_1 = 386$ deg. K, then :

$$\epsilon = \frac{386}{14} . 0.55 = 15.10 \text{ and}$$

$$\lambda = \frac{1000}{44.5} = 22.5 \text{ kg./kWhr.}$$

with a power input of 44.5 kW at the motor terminals.

Some representative examples of thermo-compressors for evaporating or distilling plants are shown in Figs. 15-16. The installation shown in Fig. 16 is especially interesting ; it is used for preparing milk sugar (lactose), as a by-product of casein and albumine. Full or skimmed milk can be also concentrated in the initial stages of manufacturing dried milk products, which are very stable and can be kept for a considerable time. In this manner, seasonal surpluses can be stored for times when there is a shortage of milk. Such plants can operate entirely without fuel, and can be paid off within a very short time.

All kinds of products can be treated, like whey and milk sugar as well as milk powder and dried milk in the spring, whereas various kinds of fruit juices can be concentrated later on in the year.

IMPORTANT UNKNOWNS IN INDUSTRIAL LUBRICATION.

By PAUL MARTINET, formerly Chief Engineer of the Vacuum Oil and French Standard Petroleum Co.
(From *Mecanique*, Paris, No. 315, July, 1943, pp. 203-209.)

IN the 60 years since Beauchamp-Tower, followed by Osborne-Reynold, put forward the theory of the pressure film in the lubrication of bearings, a considerable amount of work has been published on the subject, but the industrial application of this theory has not kept pace with the theoretical advance. Such successful applications as the Michell bearings for hydraulic and steam turbines have probable come about because of the favourable conditions for the formation of a hydrodynamic film, namely, light loading, high speeds, etc., rather than because of prior theoretical calculation.

The necessity to replace critical materials during the War has revealed that many engine-makers follow old routine methods, and that knowledge of the large amount of research and experimental work has not penetrated into industrial and manufacturing circles, although the lubrication problem is as important as that of the metals concerned in the problem of reducing wear. This failure may be due, in some measure, to the speculative mathematical presentation of results of research on this question and on the difficulty of checking hypotheses based on the microscopic dimensions of the oil films to be studied. Another reason is that engineers consider it to be the job of the lubricant suppliers to settle these matters so that co-operation between the two parties concerned has not been very close.

It is, indeed, very difficult to arrive at definite formulæ governing the production of hydrodynamic films of thickness of one micron, as it is impossible to get values for the terms of the formulæ. For example, it is impossible to determine the viscosity of a film of oil 1/10 to 1/100 mm. thick, as the temperature cannot be controlled. It is also difficult to establish the shape of the zone of contact on a shaft which has done some service and so been distorted even to the slightest degree. Finally, the mechanical side of obtaining this method of lubrication has been neglected. Theorists have been chiefly concerned in calculating the coefficient of friction to within a thousandth, but the practical man is not so interested in that as in being sure of obtaining a lubricating film under normal working conditions, to support the required loads and so keep the bearings in perfect condition at a reasonable cost. In view of the failure of theoretical experiments it seems essential to carry out actual trials to ascertain the maximum load which an oil film can support in hydrodynamic motion under the varying conditions of industrial applications.

EXPERIMENTS CARRIED OUT BY THE SOCIÉTÉ ISOTHERMOS, PARIS, AND BY THE FRENCH NATIONAL RAILWAYS (S.N.C.F.).

These experiments have given an objective knowledge of the results to be expected from viscous lubrication on the hydrodynamic principle. These results can be checked by any qualified technician, and it is hoped that many will do so.

To enable a comparison to be made with industrial engineering requirements, it is essential to define the bases on which the Railway Services have made their trials.

Pressure on journals is calculated as for ordinary bearings, i.e., pressure equals load divided by diameter by length of bearing.

Type of bearing	*Pressure per cm² approx.*	*R.p.m. approx.*
Transmission	1 to 2 kgs.	150 to 400
Electric motor, direct drive	2 to 4 kgs.	750 to 3,000
Overhung pulley motor	5 to 6 kgs.	750 to 3,000
Compressor or motor with forced lubrication	15 to 25 kgs.	1,500 to 500
Axle Journals—		
Waggon	26 kgs.	
Carriage	15½ kgs.	750

It can be agreed that the number of overheated axle boxes on Passenger coaches is practically nil by comparison with the number of journals in service and their total running time. Lubrication is with very free-running oil, and even with mazout, which some engineers would only use very unwillingly. In private industry failures of bearings due to faulty lubrication are relatively more frequent than on Rolling stock.

DIFFERENCES IN DESIGN BETWEEN STANDARD BEARINGS AND AXLE-JOURNAL BEARINGS.

Standard bearings consist of two half-bearings with oil-guard and cross grooves, or of a bush with spiral oil-grooves or without.

Diameter of shaft, D ; Diameter of bearing, D ; plus .002/ .005D.

Carriage Axle Journal, D.=140 mm. Length, 300 mm. Bearing, 144 mm bore. Width of bearing, 120 mm. No cross groove.

As can be seen, not only are the designs different, but the method adopted to control contact between bearing and shaft are very different, indeed, it would be reasonable to expect that most engineers-in-charge would refuse to adopt railway practice in their works, but results show that the railway methods are far ahead as regards friction control and, *ceteris paribus*, in the reduction of wear of bearings.

The French National Railways' Laboratory is fitted with various apparatus for testing coefficients of friction, etc. The machine for tests under pressure has a length of axle, driven by a 15 h.p. electric motor, fixed on two bearings one near the coupling and the other at the wheel seat. A complete grease box, as used on rolling stock, is fitted on the overhung part of the journal, and the axle is free to move under load as in actual running. The box is held in a stirrup on knife-edge stays, the whole forming a deformable parallelogram.

The bore of the bearing is 4 mm. larger than the axle diameter, and is approximately 120 mm. long. No oil grooves are provided, only oil holes.

The viscous hydrodynamic oil film begins to form at a relatively low speed, about 40 to 50 cm. per second. Lubricated surfaces are 16 mm. dia., 28 mm. long with 0.1 mm. play.

Even with an overbore of 4 mm., the formation of the film under pressure is extremely rapid, 750 r.p.m. is equivalent to 110 km. per hour in service. During the rise in speed from when the film first appears to a maximum speed of 5.50 m. per sec., no rise in pressure is observed, and only the shape and thickness of the film is altered. The average pressure of the film is about 72 kg., with a maximum pressure of 300 to 350 kg. in the middle. With a free supply of oil, the hydrodynamic film is assured.

Whereas the Railways must have exact knowledge of the coefficients of friction to determine draw loads, etc., this is not so essential in industrial applications. It would, therefore, only be necessary to have a simple test machine to study the formation of the hydrodynamic film, as it is known that coefficients of friction between limits of .0015 and .0025 are an inevitable consequence of perfectly lubricated running.

Fig. 1 shows a proposed machine for these tests, which would allow of :—

(*a*) Visual observation of commencement of formation of film.

(*b*) At what speed the film begins to form.

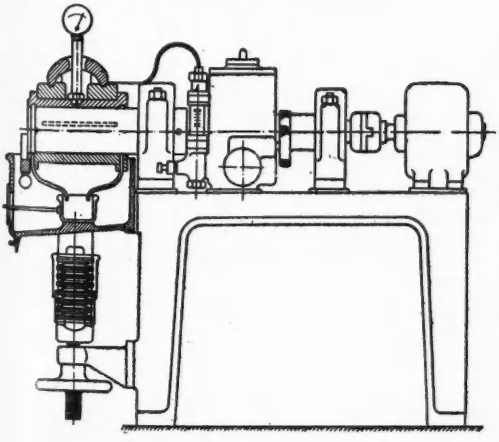


Fig. 1

(*c*) At what speed, on deceleration, it fails.

(*d*) By moving the bearing along, the active part of the bearing can be studied and the area of the film seen.

(*e*) Effects of various surface finishes on the bearing in the formation of the film.

(*g*) Measurement of loss of lubricant.

These practical results are particularly important when investigating the use of lubricant substitutes.

Bearings of anti-friction metal are probably better than in bronze or cast-iron at high pressures, as the anti-friction metal may yield a little under heavy pressure, and so allow of a thicker film of oil being set up, thus reducing the pressure, and giving a wider margin of safety.

Various split and bush-type bearings, with oil-grooves of differing designs, can be tested in this machine of which the normal dimensions might usefully be :—

Shaft diameter, 100 mm. Bore of bearing, 100 plus x.
Length of bearing, 200 mm. Oil grooves, 170 mm.
Load, 3,000 kg.
Pressure per cm² (D. L), 15 kgs.
Range of speeds, 500 to 1,000 r.p.m.
Normal bearings with longitudinal grooves, clearance on dia., 0.2 mm.

1. *Upper-half bearing loaded in centre (verical load).*

Fig 2 shows in shaded area the position of the zone of pressure, and the hydrodynamic film is formed a few cm. in front of the upper generatrix of the bearing. With a clearance of 0.2 mm., the film will form on about 4 cm. of the development of the bearing and the mean

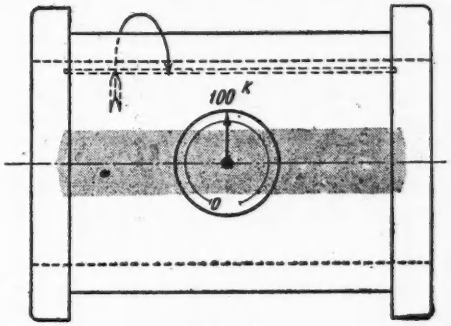


Fig. 2

pressure, ignoring taper, will be about 45 kg. with a maximum of 100 kg.

This bearing takes the load along its entire length, as the film under pressure covers the total length. This gives the following advantages in the working of the axle-box :—

(*a*) Mean and maximum pressure of the film are not high.

(*b*) Maximum thickness of film under pressure.

(*c*) Increase in safety factor of box with maximum thickness of film.

(*d*) Possibility of use of lubricants over a wide range of viscosity.

2. *Horizontal load on junction of half-bearings.*

This is the case of the load applied by a belt working horizontally. Results would be as for 1 above. Groove placed at 90 deg. in advance of the minimum thickness. It is essential to see that there is no leakage from inside to outside in the area of pressure.

3. *Bearings as in Fig. 3 with cruciform cross grooves joining inside with outside.*

This prevents the formation of an oil film in centre of bearing, but two partial films are formed as shown shaded on sketch. The pressure of these partial films

THE STRESSING OF ROTATING AIRSCREW BLADES

By P. MATTHIEU. (From *Schweizer Archiv*, Vol. 9, No. 11, November, 1943, pp. 325-336).

THE present investigation originated during the systematic development of the Escher Wyss variable pitch airscrew (Figs. 1-3) which, due to its great range of loading (airscrew as brake in landing and dive) necessitated a thorough stressing.

Since the year 1937, a number of approximate methods have been developed for the stressing of airscrew blades, e.g., by J. B. B. Owen ("Stressing of Airscrew Blades," *Aircraft Engineering*, 1940). The problem has been systematically treated in the Russian paper of Panov ("The Stress-Strain Analysis of an Airscrew," *Trans. Centr. Aero-Hydrodyn. Inst.*, No. 288, 1937). The viewpoint and presentation of that paper, however, are so very general that the results are hardly of use to the engineer. Attention has been focused in the following approximate methods on those factors which are of practical importance in stressing rotating blades. By these methods the error in the first approximation is about 5 per cent., while for the second approximation it is, for all practical purposes, negligible.

The forces we have to consider are the aero-dynamic forces and the centrifugal forces acting on each element of the blade, which is taken as initially straight and rigidly fixed in the hub. Putting the blade in the positive x-axis of a co-ordinate system with the fixed end as origin, the resultant aerodynamic force $d\bar{L}$ acting on the blade element of the length dx, and the specific aerodynamic force $\frac{d\bar{L}}{dx} = L(x)$ can be defined as a definite function of x. On each element there is also the action of the centrifugal force $d\bar{Z}$, and therefore, the specific centrifugal force $\frac{d\bar{Z}}{dx} = Z(x)$. It is permissible to assume that the functions L and Z are independent of the deformation of the blade. In a plane containing the x-axis there is the resultant thrust $Q(x)$ due to the specific aerodynamic force L, and the resultant tensile force $T(x)$ due to the centrifugal force :

$$\frac{dQ}{dx} = -L \quad \text{and} \quad \frac{dT}{dx} = -Z \qquad .. \qquad (1)$$

In accordance with aerodynamic principles, the specific force L is assumed perpendicular to the least axis of inertia of the blade sections. The next step in our approximation is to replace the twisted blade by a straight rod, the plane of which is defined by the x-axis and the least axis of inertia of some mean section, about $\frac{2}{3}R$ distant from the root. The angle between the plane of the new blade and the plane of rotation is called mean angle of pitch, φ (Fig. 6).

The actual case 1 (Fig. 4) is thus approximated by case 2, and finally replaced by case 3. The error due to the last assumption is also on the safe side and is small, as the maximum blade twist can be only about 25 deg.

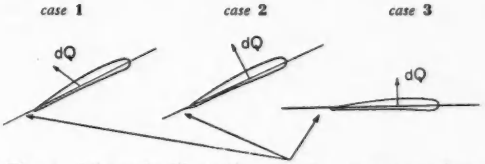


Fig. 4. **Schematic illustrations of the two assumptions.**

With these assumptions the whole problem is reduced to one of plane. The forces L and Z as well as the deformations are now in one plane, perpendicular to the plane of the blade (Fig. 6). The task will be to find the deflection curve of the blade as a function $y = f(x)$. The maximum direct stress in an arbitrary section is then given by

$$\sigma \max = \frac{M}{W} = e\,E\,y'' \qquad .. \qquad .. \qquad (2)$$

(M = bending moment, W = modulus of section, E = modulus of elasticity, e = maximum distance from neutral axis).

To determine the differential equation of the curve $y = f(x)$ the effect of L and Z must be analysed more closely. The specific force L offers no difficulty as its direction remains constant. This is not the case with the centrifugal force. Let us consider two extreme cases (Fig. 5), one for $\varphi = 90$ deg., braking position, the other for $\varphi = 90$ deg., feathering position. In the first case, the

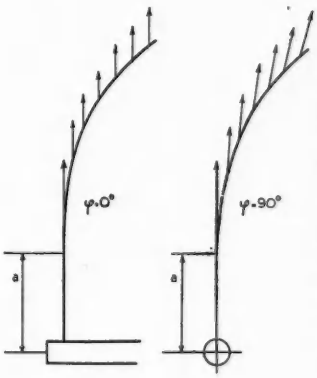


Fig. 5. **Effect of the centrifugal force for the two extreme blade positions.**

Figs. 1-3. **Escher Wyss Controllable Pitch Airscrew in various blade positions. (Feathering—Normal—Braking).**

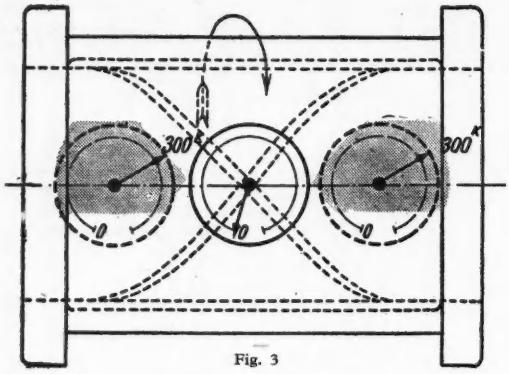


Fig. 3

is much higher, 300 kg. as against 100 kg. in 1 above, due to the smaller areas of the films and the increased leakage of lubricant. The objections to this type of grooving are :—

(*a*) It leads to too high pressure.
(*b*) Oil films are too thin.
(*c*) Necessity of using high viscosity oil to maintain safety film.
(*d*) Danger if too thin oil is used.
(*e*) Reduction in safety factor of box.
(*f*) Necessity for highly finished machining owing to miscoscopic thickness of oil film obtained.

Horizontal loading. No hydrodynamic film can be obtained as communication from inside to outside by grooves prevents any pressure being built up.

4. *Bearings as in Fig.* 4 *with spiral grooves.*

Pressure film is broken where grooves cross and disadvantages are as for bearings to Fig. 3 above.

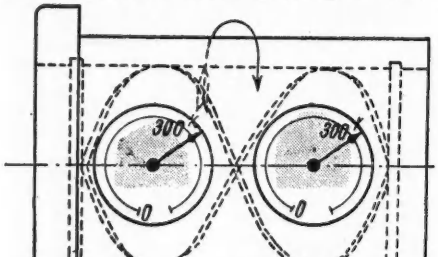


Fig. 4

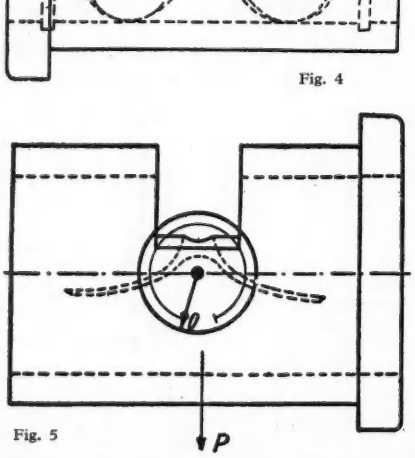


Fig. 5

5. *Sleeve bearings as in Fig.* 5 *in one piece with cross grooves.*

This type is often used when lubrication is provided by oil-throw rings, with cross grooves. If the load is applied as at *P* in Fig. 5, it is possible to obtain a pressure film on the whole length of the bearing. If the load is applied on the top of the bearing, the films on either side of ring are shorter and therefore pressure is higher. With horizontal load, the cross grooves hinder considerably the formation of the pressure film and, if they extend all along the bearing, no film will form.

UNKNOWNS.

There are three important unknowns :—

(*a*) Disturbances caused by the condition of the surface in the formation and maintenance of hydrodynamic films.

(*b*) The quantity of oil required to feed a hydrodynamic film.

(*c*) The viscosity of the oil to be used to give the required margin of safety.

Actual knowledge of these points is very indefinite, as it is not based on controlled and trustworthy experiments but only on a mass of unco-ordinated visual observations often biased by unconscious pre-conceptions. This has led to difficulties and exaggerated caution when engineers are being forced to reduce lubricating oil consumption and to use substitute materials.

(*a*) The nature of the surfaces in contact plays a very important part in the formation and retention of hydrodynamic films as can be appreciated from the fact that a film under pressure will have a thickness of between .001 and .050 mm. A test machine, as illustrated, can be used to test the effect of various grades of finished surface.

(*b*) It is obviously essential to have an adequate supply of oil, to obtain and maintain the hydrodynamic film. With oil-ring or forced lubrication this is assured but, using either an automatic or a hand greaser, it is essential to know how to regulate it on a minimum basis of lubrication. The quantity flow required, whilst proportional to the number of revolutions of the shaft, is affected by the minimum film thickness, as a large part of the oil will adhere to the surface and will not require replenishment.

Again, the thickness of the film increases with increase in revolutions, so that the amount will increase in proportion with the speed. There is also the leakage from the ends of the bearing to be considered. This cannot be estimated solely by the amount of clearance between shaft and bearing, as there is a very considerable adhesive attraction on very thin films. The ratio between length and diameter of bearing is also a factor, as is that of the viscosity of the oil used.

All these factors affecting the question of oil supply could well be studied by individual concerns, with the help of a testing machine as described in this article, and it is with a view to persuading engineers to carry out these tests that this survey has been written.

FILTER CLOTHS in SYNTHETIC MATERIALS.

(From *La Technique Moderne*, Vol. XXXV., Nos. 13 and 14, July, 1943, p. 110).

A new fibre, Pe-Ce, a polyvinyl chloride, is particularly suitable for the manufacture of Filter Cloths for the Chemical Industry. Pe-Ce Filter Cloths are inflammable and can easily be washed. They last from 6 to 10 times as long as cotton or wool cloths and about 3 to 5 times as long as those in nitro-cellulose.

Pe-Ce fibre should not be heated above 80 deg. C. It is resistant to concentrated acids (hydrochloric, sulphuric, nitric) to alkalis, oils, greases and petrol. On the other hand it does not resist chlorine, sulphurous oxide, chlorinated hydrocarbons, aromatic hydrocarbons, esters or cetones.

(2) *The influence of material (E = modulus of elasticity and γ = specific gravity) on stress and deformation.*

If Σ_{max} for a given material denotes the maximum resultant stress due to bending stresses σ_{max}, and stresses due to centrifugal force σ', we have $\Sigma_{max} = \sigma_{max} + \sigma'$. The corresponding value for a new material (index n) is then $\Sigma_{n\,max} = \sigma_{n\,max} + \sigma'_n$.

The resultant stress in the new material is given as

$$\Sigma_{n\,max} = h \frac{E_n}{E} \sigma_{max} + \frac{\gamma_n}{\gamma} \quad .. \quad (19)$$

where $h = \dfrac{1}{\dfrac{E_n}{E} + \left(\dfrac{\gamma_n}{\gamma} - \dfrac{E_n}{E}\right)k}$ .. .. (20)

These formulae are derived for the initially straight blade the dimensions of which are kept constant for the comparison. If materials of the same group are compared eq. (19) becomes

$$\Sigma_{n\,max} = \sigma_{max} + \frac{\gamma_n}{\gamma} \sigma' \quad .. \quad .. \quad (21)$$

In (21), $\sigma_{max} = \sigma_{n\,max}$, which means that using materials of the same group the stresses do not change. This does not hold for the deflections, which are, for the new material, always h times greater than the deflections of the blade of the old material. Eq. (21) shows also that if σ' is great, the blade of lighter material can reduce the stresses.

(3) *Finally, the condition of a bending-free blade axis is analysed.*

This is the case of the rotating blade in which the effect of M_L is annulled by that of M_2, i.e., no bending moment acts on the blade. The blade axis is characterised by the fact that the resultant of the aerodynamic and centrifugal forces is always in the direction of the tangent. The differential equation of this curve is

$$y'' T + y' T' - \sin^2 \varphi \frac{y}{x+a} T' + L = 0 \quad .. \quad (22)$$

The author offers two solutions to this problem.

CYLINDER WEAR MEASUREMENTS ON GERMAN AND AMERICAN ENGINES

By DIPL-ING. A. MOSER, Stuttgart. (From *D.M.Z. Deutsche Motor-Zeitschrift*, Vol. 20, No. 1, January, 1943, pp. 10-17).

EFFECT OF OPERATING CONDITIONS.

1. *Normal Wear.*

GENERALLY the largest cylinder wear takes place at t.d.c. (Fig. 1, top left). In practice, therefore, cylinder wear is very often expressed as the maximum dimension in this region, this being the criterion of the suitability of the cylinder for further usefulness. Wear diagrams illustrate the quality of cylinder and piston ring materials, the effect of lubricants on wear, correct ignition, corrosion, and other effects.

2. *Special Types of Wear.*

Naturally it is also desirable to know the wear in other parts of the cylinder bore. The results obtained very often differ, depending on the design of the particular engine and its operating conditions.

When the fuel is not completely atomized a considerable increase in wear takes place near t.d.c. decreasing approximately linearly towards b.d.c. (Fig. 1, top right). The same type of wear is observed on military vehicles which have been operating on dusty roads in Poland, Libya and Russia. The reason for this is that the piston rings near t.d.c. are running practically under conditions of dry friction.

The type of wear shown in Fig. 1 (bottom left) is comparatively often met in practice and is caused by contaminated lubricating oil. Wear debris and also fine sand which has entered through the air intake, constantly take part in the reciprocating motion of the piston, and thus cause excessive wear at the middle part of the stroke. The oil, therefore, should be completely changed, taking great care to stir it well, as otherwise abrasive particles settle out in the crankcase and become again effective when new oil is used.

Fig. 1 (bottom right) shows the wear diagram of cylinder bore, the wear having been caused by loss of water in the radiator. The cylinder material was red hot and thus the conditions of fluid lubrication were also destroyed near b.d.c. The points at which the piston rings change their direction of motion can be easily seen. The wear debris thus produced contaminated the oil; after some time of operation a wear diagram as shown in Fig. 1 (bottom left) was obtained As the three special cases of cylinder wear mentioned above are comparatively rare, in the following tests the increase in diameter at t.d.c. was measured only.

AVERAGE TIME OF OPERATION AND WEAR.

1. *Passenger Vehicles.*

It was of main interest to know whether U.S.A. vehicles compare favourably with German vehicles so far as cylinder wear is concerned. Table 1 shows the results of about 500 measurements carried out to investigate this point, distinguishing between different engine sizes. Whilst German engines were mostly of less than 2 litre total cylinder capacity, the capacity of the American engines used was mainly larger. The

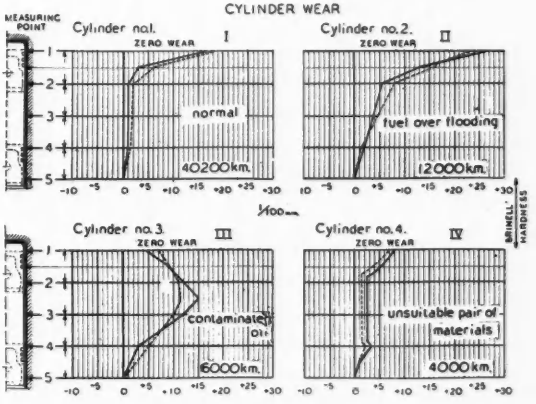


Fig. 1. **Typical wear diagram.**

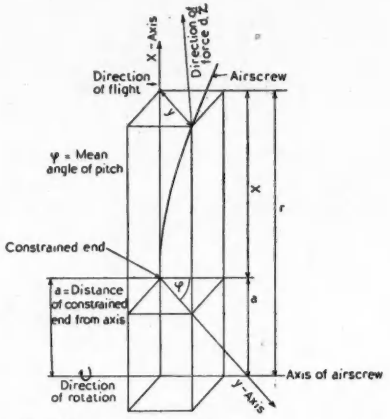


Fig. 6. The Airscrew blade and forces acting upon it.

centrifugal forces are still in the same direction, in the second, the centrifugal forces change direction as they are acting radially from the axis. The general case lies between the two extremes. Consider this with reference to Fig. 6; on the element of length dx the centrifugal force be $d\bar{Z}$. This can be split into three components, of which two are of interest: the component parallel to the x-axis of the magnitude $d\bar{Z}\,\frac{r}{\sqrt{r^2+y^2\sin^2\varphi}}$, and that parallel to the y-axis of the magnitude $d\bar{Z}\,\frac{y\sin^2\varphi}{\sqrt{r^2+y^2\sin^2\varphi}}$. As the deflection y is small when compared to radius r, the denominators of the above terms are approximately equal to r. Thus, the forces on the rotating blade are:

$$\left.\begin{array}{ll}\text{in the } x\text{-direction} & \ldots\ Z,\\ \text{in the } y\text{-direction} & \ldots\ L + Z\,\dfrac{y\sin^2\varphi}{x+a}\end{array}\right\} \ldots \quad (3)$$

Either of the two loads given by eq. (3) introduces a bending moment. These bending moments are of opposite sign, and are denoted here as $\bar{M}_1$ and $\bar{M}_2$.

Then we have $$\frac{d^2\bar{M}_1}{dy^2} = \frac{d\bar{Z}}{dy} = \frac{Z}{y'} \quad \ldots \quad (4)$$

$$\frac{d^2\bar{M}_2}{dx^2} = L + Z\,\frac{y}{x+a}\sin^2\varphi \quad \ldots \quad (5)$$

From eq. (1) and eq. (4) it follows that $\frac{d\bar{M}_1}{dy} = -T$ (6)

and herefrom,

$$\frac{d\bar{M}_1}{dx} = -T\frac{dy}{dx} \text{ and } \frac{d^2\bar{M}_1}{dx^2} = -\frac{d}{dx}\left(T\frac{dy}{dx}\right) \quad (7)$$

As $\bar{M}_1$ *and* $\bar{M}_2$ are counteracting each other, the actual moment is

$$M = \bar{M}_2 - \bar{M}_1 \quad \ldots \quad (8)$$

and further $$M = \bar{M}_2 - \bar{M}_1 = E\mathcal{J}y'' \quad \ldots \quad (9)$$

($\mathcal{J}$ = moment of inertia).

Eq. (9) twice differentiated and taking (8), (5) and (7) into account yields the final differential equation of the blade deflection curve

$$\frac{d}{dx^2}\left(E\mathcal{J}\frac{d^2y}{dx^2}\right) = L + Z\,\frac{y}{x+a}\sin^2\varphi + \frac{d}{dx}\left(T\frac{dy}{dx}\right) \quad (10)$$

This fourth degree equation is difficult to integrate and therefore further approximate assumptions are made by the author, which reduce the complicated eq. (10) to

$$E\mathcal{J}y'' = (1-k)\,M_L \quad \ldots \quad (11)$$

(M_L is the moment due to the aerodynamical force, k a factor dependent on the aerodynamic data of the airscrew. Also, $k = \frac{M_Z}{M_L}$, where M_Z is the moment due to the centrifugal force).

It is simple to integrate first the equation—

$$E\mathcal{J}y'' = M_L \quad \ldots \quad (12)$$

The resulting curve being $y = f_2(x) = \frac{1}{1-k}f(x)$ (13)

where $y = f(x)$ is the true deflection curve due to eq. (11), ($y = f_1(x)$ is the curve of the initially undeflected blade, i.e., $f_1(x) \equiv 0$).

If we imagine the blade defined by $y = f_2(x)$ rotating, the action of the centrifugal force will lead to just another deflection of the blade expressed as $y = f_3(x)$.

Then, $$f_3(x) = \frac{1-\frac{k}{1-k}}{1-k}f(x) \quad \ldots \quad (14)$$

From eqs. (13) and (14) k can be calculated.

Thus we have

$$k = \frac{f_2(x)-f_3(x)}{2f_2(x)-f_3(x)} = \frac{a_2-a_3}{2a_2-a_3} \quad \ldots \quad (15)$$

where a_2 and a_3 are the ordinates obtained by intersecting the curves $y = f_2(x)$ and $y = f_3(x)$ by an arbitrary straight line g parallel to the y = axis. All this is shown in Fig. 7.

Substituting (15) into (13) we obtain

$$f(x) = \frac{a_2}{2a_2-a_3}f_2(x) \quad \ldots \quad (16)$$

This is the principle of the method developed in the original paper in detailed points.

In the following a short survey is given of various other aspects dealt with in the original paper.

1. *Extension of above formulae to cover the case of an initially bent blade.*

In this case the initial deflection can be expressed as $y = f_1(x) \neq 0$, and this curve in Fig. 7 would be cut

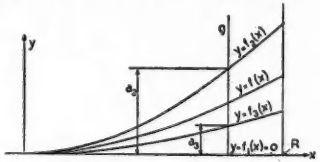


Fig. 7. Diagram showing functions $f_1(x)$, $f_2(x)$, $f_3(x)$ and $f(x)$,

by line g in a distance a_1 from the x-axis. The corresponding value for k is then given by

$$k = \frac{(a_2-a_1)-(a_3-a_1)}{2(a_2-a_1)-(a_3-a_1)} \quad \ldots \quad (17)$$

The final deflection curve is similar to eq. (16), and is of the form

$$f(x)-f_1(x) = \frac{a_2-a_1}{2(a_2-a_1)-(a_3-a_1)}\left[f_2(x)-f_1(x)\right] \quad (18)$$

the various engines. Average values provide a basis for comparison. The limiting values actually obtained show considerable scatter with the exception of motor cycle engines.

EFFECT OF DESIGN.

1. *Piston Design and Material (Light Alloy and Iron).*

(a) What is the influence of piston material (cast iron and light alloy) on cylinder wear? Generally it has been assumed that cast iron pistons are better as far as cylinder wear is concerned. The results given in Table 3 show that cylinder wear is practically independent of piston material. For Invar strut pistons the values are slightly lower, as these pistons are fitted only to small engines of less than 2 litre capacity which, because of their higher power-weight ratios, operate near their maximum power.

TABLE 3

Distance covered in km., related to 0.01 mm. cylinder wear.

Piston Material and Design		Passenger Vehicles German	Passenger Vehicles American
Light Alloy Pistons	Invar Strut Pistons	2570 many amongst them of more than 2 litre capacity	2860
	solid skirt and split skirt pistons	2640	2860
Cast Iron Pistons	Iron casting and half-steel pistons	2660	3140

(b) Offset Gudgeon Pins. When the connecting rod is in an inclined position the piston is pressed against one side of the cylinder wall. To neutralize this effect the gudgeon pins are sometimes offset from the centre. So far, no effect on cylinder wear has been detected.

(c) Cylinder Protection. Furthermore, in recent years cylinders have been protected with a layer of tin, lead, or graphite against wear during running in and cold starting. Measurements carried out on such cylinders showed no definite difference in wear.

2. *Engine Design and Material.*

(a) Number of cylinders (Fig. 3). Measurements on four-cylinder engines give an average of 45,000 to 50,000 km. before major overhaul, the wear at t.d.c. being generally about 0.32 mm. With six-cylinder engines the distance covered before rebore is about 30 per cent higher, the wear being about 20 per cent smaller. The difference between eight and six-cylinder engines is not so pronounced, higher mileages being obtained without any increase in wear. These comparisons only refer to German engines mostly of one make, bore, stroke, and other dimensions. These differences in total mileage before major overhaul and wear are probably due to the fact that four-cylinder engines do not run so smoothly as those of six or eight-cylinders, and that the power-weight ratios decrease with an increasing number of cylinders.

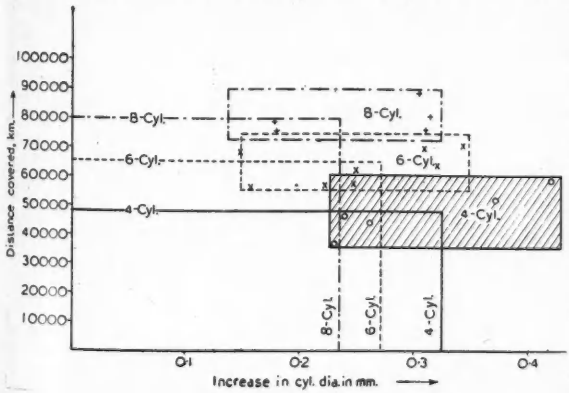


Fig. 3. **Influence of number of cylinders upon wear and distance covered with passenger car engines.**

(b) An attempt has also been made to correlate the wear at t.d.c. and along the whole length of the cylinder with piston velocity. According to the theory of wear, if two surfaces are rubbing against each other, the wear increases with decreased rubbing speed. As this is only valid for dry or nearly dry friction, it applies to the zone near t.d.c. only. Under normal conditions, near t.d.c. there is fluid lubrication without any noticeable wear. The engines showed no wear in the region b.d.c.

(c) The assumption that cold engines give more wear than engines which are uniformly warm has been found correct, practically no wear having been found on vehicles which took part in the uninterrupted 30-day journey on the Nürburgring on dust-free roads.

(d) Cooling System. It is a characteristic of some engines, that the wear of the first cylinder bore facing the wind, and also often nearest to the cooling water entry, is 10 to 20 per cent higher than that of the other bores. The cooling system should, therefore, be designed so as to keep the different cylinders at the same temperature to obtain the same conditions of wear.

(e) The question, whether cylinder wear of air-cooled engines is higher than that of water-cooled engines, cannot be satisfactorily answered as a sufficient number of measurements have not been taken. Recently, however, the experience gained with air-cooled engines has been satisfactory.

(f) Campaigns in Poland, Greece, Libya, and Russia showed that contaminents in the oil cause a great amount of wear. What improvement can be obtained by choosing appropriate materials for the rubbing surfaces and by still better air filtration, is a question of major importance.

(g) Many tests were carried out to investigate the effect of cylinder hardness on wear. No definite difference was detected in Brinell hardness between about 180 and 240. Structural differences of the materials are probably of higher importance.

(h) Too high oil consumption of a relatively new engine seems to result in greater wear. Five engines of the same type, the oil consumption of which was too high, gave a wear of 0.01 mm. over 1875 km. after a total of about 40,000 km., while another six engines of the same type with normal oil consumption gave a wear of 0.01 mm. per 2750 km.

(i) Measurements showed that good air filtration is specially important with rear engined cars. 22 vehicles (nearly 90 bores) gave an average wear of 0.01 mm. per 1734 km. With engines at the front, a wear of 0.01 mm. per 2350 km. was obtained, an improvement of about 40 per cent. In another case of 20 vehicles, the wear of the rear engined vehicles was 20 per cent less than that of the front engined vehicles.

(k) Measurements on cylinders of tractor engines have not been carried out in sufficiently large numbers. Under particularly severe conditions of dust, the maximum engine life might be expected to be about 1000 hours. This can be approximately doubled and trebled by using groove inserts and nitrided cylinder liners. Again, this improvement is due to the fact that here also the top third of the cylinder, the piston land, and the piston rings suffer most.

distances covered before major overhaul was, with German engines of :—

0.75-1.25 litre capacity	about 52,000 km. (max. 105,000, min. 23,000) km. ;
1.25-2.0 litre capacity	about 64,000 km. (max. 129,000, min. 23,000) km. ;
2.0-5.0 litre capacity	about 71,000 km. (max. 185,000, min. 21,000) km. ;
and with U.S.A. engines of 2.0-5.0 litre capacity	about 72,000 km. (max. 168,000, min. 20,000) km.

TABLE 1
Cylinder wear and distance covered before major overhaul of German and American engines.

	German vehicles			U.S.A. vehicles 2-5 litres
	0.75-2.0 litres		2-5 litres	
	0.75-1.25	1.25-2.0		
Vehicle types	13	22	13	14
No. of vehicles	172	259	102	90
km. : Average	52,000	64,000	71,000	72,000
max.	105,000	129,000	185,000	168,000
min.	23,000	23,000	21,000	20,000
Wear : Average	0.23	0.27	0.24	0.24
max.	0.63	0.90	0.55	0.69
km./0.01 mm. wear	2310	2370	2960	3000
H.P.	23	35	52	67
Total cylinder capacity litres	1.0	1.75	2.6	3.4
Weight of vehicle kg.	740	1070	1630	1370
Weight-power ratio kg./h.p.	32	30	31	21

The mileage of the American vehicles before major overhaul was therefore slightly higher than that of the German engines of about the same power, and nearly 40 per cent larger than that obtained with small German engines. The average wear at t.d.c. was the same for both German and American engines, that is between 0.23 and 0.27 (max. 0.90). With engines up to 2 litre capacity there was an average wear at t.d.c. of 0.01 mm. per 2350 km., and with engines of more than 2 litre capacity this wear was obtained after about 3000 km. American engines are found to be only slightly better than corresponding German engines of the same power. This is probably due to the difference in power-weight ratio between corresponding German and American vehicles. With the latter the power-weight ratio is very nearly 20 kg./h.p., while with German vehicles it is nearly 30 kg./h.p.

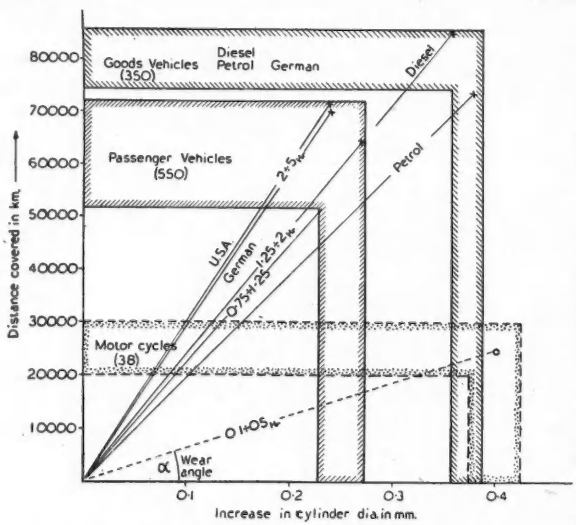


Fig. 2. Cylinder wear and distance covered before rebore.

Because of the abundance of fuel in U.S.A., American engines are designed to give an average h.p. of 67 with a total cylinder capacity of about 4.3 litres. Even neglecting the more frequently occurring vehicles of less than 2 litre capacity, the corresponding German engines have a total cylinder capacity of about 2.6 litres and a power of 52 h.p. German vehicles, therefore, operate nearer to the maximum available power than American engines.

2. *Goods Vehicles.*

A further question very often discussed is :—Why is the piston life of goods vehicles longer than that of passenger vehicles? Comparative measurements could only be carried out reliably on German engines of more than 2 litre total cylinder capacity. Table 2 gives the result of about 400 measurements, passenger vehicles of more than 2 litre capacity only being used for comparison

TABLE 2
Cylinder wear and distance covered before rebore—Passenger vehicles and lorries.

	Passenger vehicles 2-5 litres	Lorries	
		Petrol	Diesel
Vehicle types	13	12	21
No. of vehicles	102	45	248
km. : Average	71,000	74,000	85,000
max.	185,000	250,000	300,000
min.	21,000	29,000	22,700
Wear : Average	0.24	0.38	0.36
max.	0.55	0.94	0.96
km./0.01 mm. wear	2960	1950	2420

The results show that, in spite of higher cylinder wear, the average mileage before overhaul with petrol engined lorries is, against any expectation, only slightly higher than that of larger passenger vehicles. The reason for this apparently is that, as far as total cylinder capacity is concerned, the engines hardly differ from those of larger passenger vehicles ; they are built into small goods vehicles only. Here it would seem that the engines are subjected to loading conditions similar to those of passenger vehicles of less than 2 litre capacity. The cylinder wear is in both cases roughly 50 per cent higher than that with large passenger vehicles. In addition to this, lorries operate under more severe conditions, as frequently less maintenance is necessary.

Table 2 also shows the comparison of diesel and petrol engined lorries. In spite of the high pressure occurring in diesel engines, the wear of 0.01 mm. per 2420 km. is about 20 per cent less than the average wear of 0.01 mm. per 1950 km. with petrol engines.

The mileage before major overhaul of diesel operated lorries is on the other hand about 20 per cent higher than that of petrol engined lorries and heavier passenger vehicles.

On the whole, therefore, the mileage of lorries is greater than that of passenger vehicles, that is, the lorries are used for a longer time than passenger vehicles before reboring the cylinders is necessary. In the former case economy alone is the deciding factor (increasing oil and fuel consumption) whilst in the latter, noise and performance are decisive.

3. *Motor Cycles.*

Measurements on 38 engines of ten different types were carried out. The engines had been running between 19,000 and 38,000 km., giving an average of 25,000 km. before reboring. The wear at t.d.c. was between 0.25 and 0.65 mm., that is, 0.01 mm. per 625 km.

Motor cycles, as compared with lorries and passenger vehicles, have a considerably shorter life of operation. This can be seen from Fig. 2 where mileage has been plotted against wear for

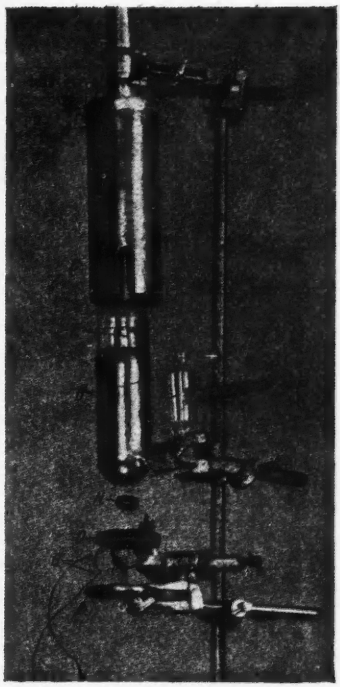


Fig. 3

III. DESIGN OF A PERMANENT-CURRENT ELECTRO-MAGNET.

Figs. 2 and 3 show the apparatus used for the experiments. The core ($A\,B\,C$) of the magnet surrounds, like a jar, the refrigerant (M) on all sides, except at the bottom, where the induction coil (O) is placed. Thus a toally enclosed space is formed where the boiling pressure of the liquid hydrogen (M) and thereby the temperature of the ring (N) can be reduced by the vacuum pump connected at (L). Fig. 1 shows how the critical value H_{kr} of the magnetic field and thereby the maximum intensity of the permanent current in the super-conductor may be increased by increasing the vacuum.

The core of the magnet is of ordinary steel. It consists of a disc (A), 70 mm. diameter and 5 mm. thick; a pipe (B) 1.5 mm. thick, 180 mm. long and 70 mm. diam., and the inner core (C) 10 mm. diam. A and B are soldered together and C is screwed into A. The liquid hydrogen is filled in through the fitting (L) which is soldered to (A). The hydrogen container (E) is a hollow double-walled cylinder of V-shaped cross section. Vacuum must be maintained between the double-walls to ensure the most perfect heat insulation and for this purpose an intermittent operated vacuum pump is connected to (F). The shape of the hydrogen container allows the core of the magnet and the induction coil (O) to be kept at room temperature while the subcritical temperature of the ring (N) is maintained.

The ring (N) is pressed at high pressure from Niob-metal powder and sintered in high grade vacuum at 1500 deg. C. It is subsequently put in a nitrogen stream and nitrated at 1250 deg. C. This treatment gave this material its name "Niobnitrid" (NbN). However, it has a deficiency in nitrogen; furthermore, it has a very complicated crystallographic structure and contains small quantities of various metals which influence its critical temperature to a great extent.

The coil (O) has 487 turns of silk-insulated copper wire of 0.3 mm. dia., 13.8 ohms resistance and is connected over a rheostat and an ammeter to a battery of at least 70 V.P.C.

The keeper P of the magnet like the disc A, is 5 mm. thick and is about 70 mm. diam. The hook in the centre serves for suspending the weight. Fig. 4 shows the apparatus in working order the induction coil just being connected to the battery.

IV. THE EXPERIMENT.

High grade vacuum having been established between the double-walls of the heat insulating hydrogen container, approximately 60 cu. cm. hydrogen is filled in. The current in coil (O) is set so that a weight of 2 kg. is just held by the electro-magnetic force. When the current is interrupted the weight must fall off immediately. Now (K) is closed and the vacuum pump connected to (F). The boiling pressure drops rapidly until the freezing point of the hydrogen is reached at a pressure of 54 Torr. (1 Torr. = 1 mm. Hg-column).

Upon reaching this pressure the pump extracts the melting heat from H_2. Then the pressure of the now sublimating H_2 drops rapidly towards the limit set by the pump itself and by unavoidable leakages in the heat insulation. The obtainable limit is in the range of 2 Torr., corresponding to 10 deg. abs.

It follows from what is stated in section two that the induction coil must be switched on in time to enable the field to enter the super-conductor. In the given example the magnetic field H necessary to hold a weight of 2 kg. is 118 Oersted and the current in coil (O) is set to produce this value approximately. Thus if the coil is switched on at a temperature where the critical field H_{kr} already exceeds this value, the field will fail to enter the super-conductor. In the given case the coil must be energised before the temperature of the conductor becomes as low as 12.4 deg. abs. or the pressure

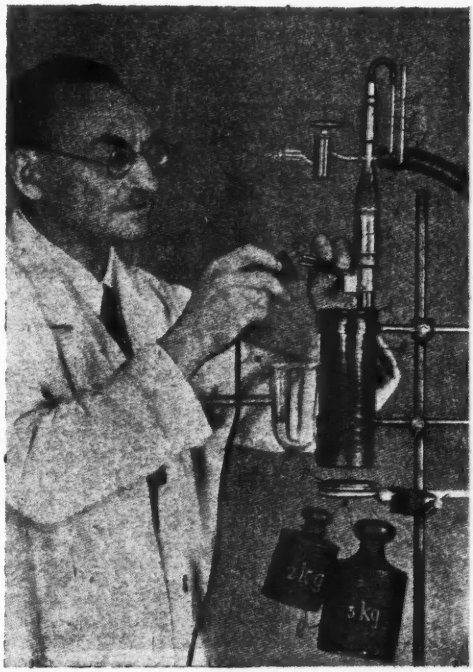


Fig. 4.

A PERMANENT-CURRENT ELECTRO-MAGNET

By EDUARD JUSTI, Berlin. (From *Electrotechnische Zeitschrift*, Vol. 63, Nos. 49/50, December, 1942, pp. 577-580).

I. GENERAL.

THE discovery of the super-conductivity of electrical-conductors in 1911 proved that at the boiling temperature of Helium (t=—269 deg. C.=4.2 deg. abs.) electrical currents flow without the usual losses (conversion into heat) and that once a flow of current is established under these conditions, it continues to flow until the temperature of the conductor is raised above the critical value $T_{ü}$ when it loses its super-conductivity.

Subsequent research work resulted in raising the critical temperature $T_{ü}$ at which the ohmic resistance almost suddenly disappears to 7.3 deg. abs. for *Pb*, 9.35 deg. abs. for *Nb* and finally to 23 deg. abs. for *NbH*. Thus the design of an electromagnet excited by a current flowing permanently, because without losses, in a closed super-conductor, became technically possible and the practical application of this phenomenon on a large scale came within reach, if it was anticipated that further research work would develop materials with critical temperatures in the range of the temperature of liquid air (60 deg. $\leqq T \leqq$ 90 deg. abs.), which industry produces in large quantities. Amongst the advantages of such a magnet would be its much higher induction when compared with the normal permanent-magnet and the saving of energy when compared with the usual electro-magnet.

II. THEORY OF THE PERMANENT-CURRENT ELECTRO-MAGNET.

The magnetic properties of a closed super-conductor of, for instance, ring shape, can be explained by the Second Maxwell's Equation.

$$B = -c.\ rot\ E$$

and the conclusion derived therefrom is sufficient for any practical application, no matter whether the ohmic resistance of a super-conductor is exactly zero or only very near zero; a problem which at the present stage cannot be solved because of the difficulties involved. In practical measuring, the conductivity σ may be assumed ∞, and the tangential component E_t of the electric field within the super-conductor practically zero.

With $E_t = 0$, the normal component $rot_n E$, of $rot E$ becomes zero according to definition of *rot* E. The normal component of the magnetic induction being $B_n = -c\ rot_n\ E = O$, the temporal changes of B_n are equally zero. This means that the magnetic flux $\int B_n\, df$ in a closed super-conductor remains constant to whatever changes the outer magnetic fields may be subjected.

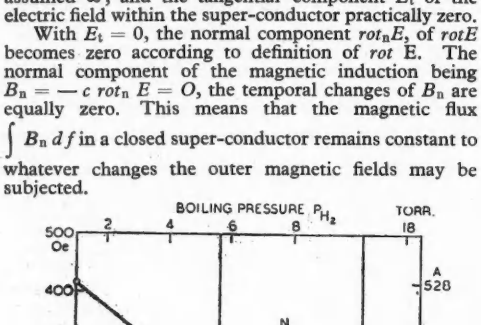


Fig. 1

Fig. 1 shows the critical temperature as function of the two variables T (temperature) and H (magnetic field). The curve separates the area N of normal conductivity from the area S of super-conductivity. The scale at the right hand side of the diagram shows the value of the permanent-current in amperes, as calculated from the value of the magnetic field H, using the equation $H_{kr} = \frac{0.2\ I_{kr}}{r}$. The inner diameter of the ring is 1.6 cm. The diagram was plotted from experiments referred to in section 4.

Fig. 1 shows that the current carrying capacity of a super conductor is also limited due to the magnetic field H associated with the current. Fig. 1 also shows that the larger the current required the more the temperature must be reduced below the critical temperature required for $H = O$, thus preventing H from increasing above H_{kr} and destroying thereby the super-conductivity of the ring.

As Ohm's law loses its validity and as there is a critical value for the magnetic field, the multi-turn type of winding used for ordinary electro-magnets may be replaced by a single closed ring. The energy inherent in such a winding carrying a current I is purely magnetic and its value is given by the equation $\frac{L\ I^2}{2}$. This energy must, of course, be supplied from the outside if a permanent current is to be set up. This is done by an induction coil which, through shock, starts up the current in the super-conductor and supplies the energy needed at the outset to create the magnetic field.

To enable an outer magnetic field to enter a super-conductor in spite of the condition $B_n = O$ valid for the latter, the field set up by the induction coil must exceed the critical value H_{kr} thus temporarily destroying the super-conductivity of the ring, while its low temperature is maintained. Upon switching off the current in the induction coil, the field in and around the ring diminishes but "freezes" when reaching the value H_{kr}. At this instant the super-conductivity of the ring is restored and the permanent current installed, the inherent magnetic energy $\frac{L\ I^2}{2}$ having been supplied through the induction coil.

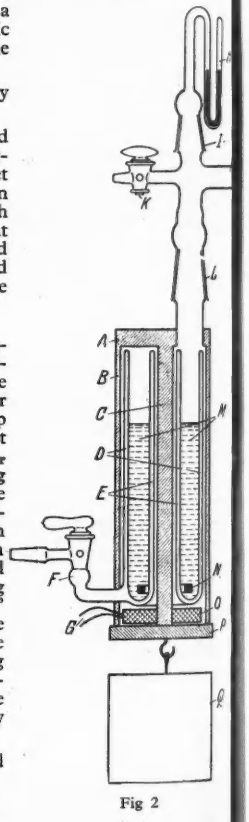


Fig 2

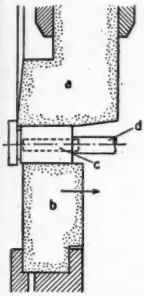


Fig. 4. **Combined shoulder and cylindrical surface grinding.**

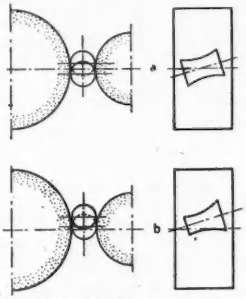


Fig. 5. **Faulty shoulder work grinding originating from wrong adjustment.**

movement of the piece between the grinding wheels. In order to secure proper contact of the piece with the stop, the regulating wheel is tilted at an angle of $\frac{1}{4}$ to $\frac{1}{2}$ degree. Stop and operating levers are mechanically linked, the stop being made to act as an ejector when the operating lever is moved to open the grinding throat.

Shoulder work of the kind illustrated in Fig. 4 is carried out with the use of cup-type grinding wheels, while the regulating wheel, tilted at an angle of 1-1$\frac{1}{4}$ degrees, is axially adjustable in accordance with the wear of the cup wheel face. In shoulder work it may often be found difficult to detect mistakes made in the setting of the machine. If, for instance, the axis of the pieces is out of alignment with the grinding wheel spindle, hollow grinding or hollow conical grinding of the piece may occur, as indicated in Fig. 5, *a* and *b*. In cases of this kind, correct adjustment of the slide will be the only remedy.

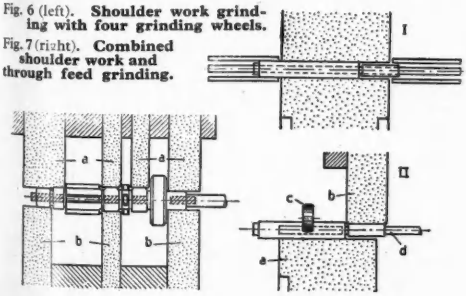
As grinding wheels of considerable width are employed in centreless grinders, form work can be executed by using several grinding wheels kept at correct distances by bushes. A typical case of this kind in which four grinding wheels are employed for grinding to five different diameters, is illustrated in Fig. 6.

Maintenance of close tolerances and of accuracy of contour is facilitated by carrying out the grinding process in several stages. A typical case of this kind is shown in Fig. 7, which refers to an axle exceeding in length the width of the grinding wheel. Here, the large axle diameter is ground with the use of the through feed method (Fig. 7, I.), while the shoulder work method is employed for grinding the small diameter portion. A lever-operated roller support is used to press the piece against the regulating wheel *b*, with the narrow grinding wheel *a* performing the shoulder work.

Subdivision of the grinding operation in several stages is also resorted to where both concentric and eccentric peripheral surfaces are to be ground, as for instance, in the case of crankshafts. After first grinding the concentric parts, eccentric bushes are put in place, these bushes being guided by roller supports. The second grinding stage then consists in grinding the eccentric parts, as e.g., the crank-pins.

Fig. 6 (left). **Shoulder work grinding with four grinding wheels.**

Fig. 7 (right). **Combined shoulder work and through feed grinding.**



In precision grinding a piece of the shape shown in Figs. 8a, b, and c, to an accuracy of 0.002 mm., grinding is carried out in three stages as shown. As the diameter of the piece exceeds its length, additional guidance is required to keep the piece from tipping over. The spring-loaded roller *c* is therefore provided, which presses the guiding bush *e* against the regulating wheel. The latter is adjusted to tilt away from the grinding wheel, so that grinding bush and work piece tend to escape from the grinding wheel, but this escape is prevented by stop *d*, which can be adjusted during the grinding process. Both faces of the piece are ground in this manner. In stage II., the chamfers of the piece are ground by means of another grinding wheel, while in stage III. the cylindrical part of the piece is ground in the usual manner.

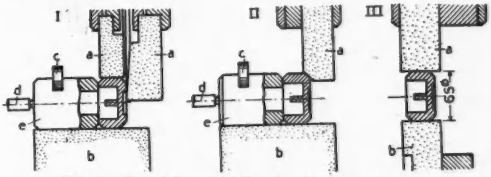


Fig. 8. **Precision grinding in three stages.**

Special Devices.

A centreless grinding machine (Fig. 9) equipped with the automatic shoulder work device *a* eliminated manual operation of the wheel lever, but manual operation of the feeding and ejecting mechanisms is retained.

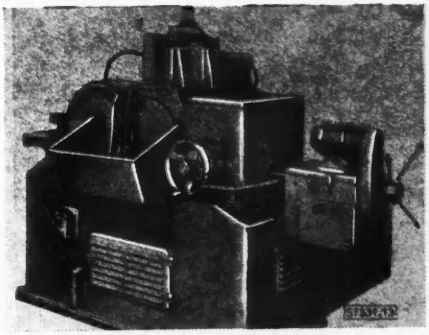


Fig. 9. **Center-less grinding machine with device for automatic shoulder work grinding.**

Fig. 10. **Automatically fed centreless grinder for grinding small bushes.**

below 18 Torr. (Fig. 1). If the temperature is now reduced below 12.4 deg. abs. and the current switched off, the weight Q will not fall, but will be held through the permanent current set up in the super-conductor N.

The experiment reversed confirms the theory. If the pump is disconnected and the temperature is allowed to rise again, the 2 kg. weight will fall off at 18 Torr. Experiments were carried out with various weights and the results plotted in Figs. 1 and 5 taking into account the dimensions of the magnet and using the formula $Q = 0.04 \times \left(\frac{B}{1000}\right)^2 \times f$ (kg.) for the strength of the magnet. These diagrams also show the intensities of the permanent currents flowing in the super-conductor N as derived from the ampere-turns necessary to hold the given weight. It was assumed that an equal number of ampere-turns was necessary to hold the weight whether the magnet was excited by the induction coil (487 turns) or by the ring N (= 1 turn). The magnetic induction was found to be well above 15,000 gauss at 2 Torr. pressure, which is higher than any induction reached with permanent magnets. It is worth noting that the permanent current flowing in N reached 500 A at 10 deg. abs. (—263 deg. C.)

V. CONCLUSIONS.

These experiments proved that the super-conductivity was not confined to the lowest temperatures. The fact that the critical temperature varies with the chemical, crystallographical and other qualities of the materials and that there are even differences between samples manufactured by the same method, opens the possibility that the critical temperature may be raised to a point where maintenance would become less expensive than are the electrical losses in ordinary electro-magnets.

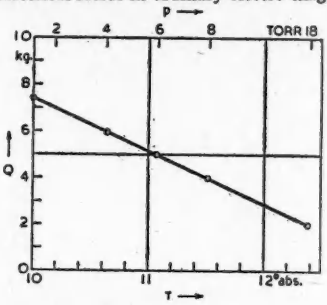


Fig. 5

CENTRELESS GRINDING IN MASS PRODUCTION

By W. HANDEL. (From *Werkstattstechnik, Der Betrieb*, Vol. 37/22, No. 4, April, 1943, pp. 149-152).

BESIDES obviating the need for centering the work pieces in the machine, centreless grinding enables the application of through feed grinding in which the work pieces are fed into the machine in unbroken succession. Also, by employing especially broad grinding wheels, a great weight of stock removal can be obtained, thereby affording a great saving in production time in the case of shoulder work, where the entire length of the work piece is to be ground in a single operation. Compared with grinding between centres, centreless grinding requires only one-third to one-tenth of grinding time.

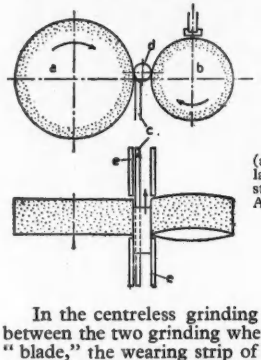


Fig. 1.
Schematic representation of grinding operation.
(a) Grinding wheel; (b) Regulating wheel; (c) Wearing strip; (d) Work piece; (e) Adjustable slide.

In the centreless grinding process, the work is led between the two grinding wheels by means of a slide or "blade," the wearing strip of which slants towards the feed or "regulating wheel." The stock removal proper is carried out by the grinding wheel *a* (Fig. 1), while the regulating wheel *b* supports the work piece *d* and guides it during the grinding process. The grinding wheel rotates with the commonly used peripheral cutting speed of 35 metres per second. The regulating wheel, which is rubber-bonded, rotates with a smaller peripheral speed, which can be adjusted to between 0.3-4 metres per second.

In the through feed process the regulating wheel spindle is placed at an angle of some 2-5 degrees to the axis of the grinding wheel spindle, the angle determining the rate of feed of the piece in the direction of the arrow (Fig. 1). In order to secure three-point support of the

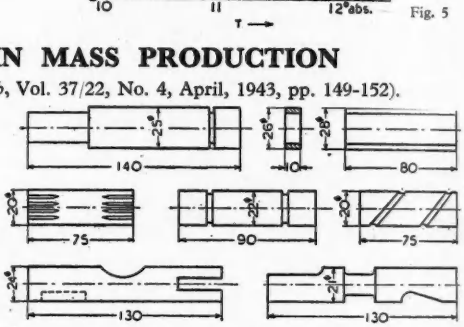


Fig. 2. **Typical work pieces that can be ground by the centreless grinding method.**

work piece, its axis is elevated by the distance H, above a line drawn through the centres of grinding wheel and regulating wheel. This elevation must be taken into account when dressing the grinding wheel in order to ensure straight line contact of the obliquely disposed regulating wheel with the piece.

The pieces outlined in Fig. 2 represent typical examples of the application of centreless grinding. The importance of their accurate feeding into the grinding throat is emphasized in Fig. 3, which shows the inaccuracies caused by a faulty lining-up of the slides.

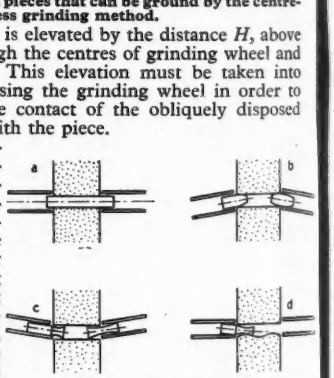


Fig. 3. **Inaccuracies incurred with incorrect grinding.**

Shoulder Work.

For carrying out shoulder work in the centreless grinding machine, a stop is provided to obviate axial

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- ✦ NEW EQUIPMENT
- ✦ BOOKS AND CATALOGUES
- ✦ BUSINESS CHANGES
- ✦ PERSONAL
- ✦ NOTES

COMBINED FOLDING AND BENDING MACHINE.

AIRCRAFT manufacturers and others concerned with the production and use of curved drawn sections will be interested in a new machine, the Fairey "Benfold" which has been developed by the Fairey Aviation Co. Ltd. This fully patented machine combines the separate operations of making straight length of section and producing the required profile or curve, which were formerly carried out on the draw-bench and by hand or in a press.

The Benfold principle is of dual application. In one application it combines a draw-bench action with a bending process, by passing the straight strip of raw material through flexibly-linked dies working in conjunction with a master former-bar, which determines the resultant section, whilst the set of the bar determines the bend or profile. In the other application, the raw material is blanked out to the required plan contour and then passed through the machine for forming the cross-section.

In operation, the raw material is clamped to the former-bar and is forced through the dies by a single or double sprocket-driver, the teeth of which engage holes located along the length of the bar. Two interchangeable working heads are provided for use in either the vertical or the horizontal plane and can be changed over in ten minutes, the dies are linked to swing horizontally or laterally, thus affording the operator the closest approach to the machine.

In general section up to 16 S.W.G., power is provided by a ¾ h.p. totally enclosed electric motor, the drive being transmitted via belt, variable gear, final chain, and either a dog or friction clutch to the sprocket. Control is effected by hand-lever or hand-wheel, a hand-wheel is also available for turning the driver when the clutch is out and a workpiece is being inserted in the machine.

Aircraft components such as, main and nose rib booms, fore and aft wing stiffeners, bulkhead flanges, formers for monocoques and ribs for floats can be manufactured on the Benfold, and the edges of the parts are entirely free of wrinkles.

COPE IMPROVED COLLET CHUCK.

W. COMPTON COPE, of 40, Jobs Lane, Coventry, has marketed an improved collet chuck the object of which is to provide axial location of workpieces; improved gripping power; compactness; confine the stresses of gripping within the collet head, where it is strongest, thus obviating broken collets through introducing stresses into the shank; and to improve precision.

The chuck consists of a cylindrical body adapted for attachment to the machine and has an open ended axial socket with an abutment to receive and locate the collet which is externally screw-threaded on the inner end, and to receive a retaining ring for the purpose of preventing the collet from moving forward with, and jamming in the collet contracting cap. The cap, mounted on plain precision registers on the outer end of the body, is operated by a differential tandem screw-threaded rotatable sleeve which engages a coarse threaded portion of the body and a finer threaded portion of the cap, thus giving a small advance of the cap for a greater advance of the sleeve and exerts a powerful pressure on the collet.

The chucks may be used on dividing heads; cylindrical grinders; milling machines; lathes; internal and universal grinders; sine tables for use on surface grinders and toolroom shapers-cutter grinders; for making press tools; punches; internal screw thread chasers; end mills; end cutting form tools; and by means of special pads, doweled to prevent rotation and inserted in the largest size collet, small eccentric pins, cams and cutters have been machined and ground.

Width of Chip Breakers for Wimet Tipped Tools.—Messrs. A. C. Wickman Ltd., Tile Hill, Coventry, have issued a most useful chart giving the recommended width of chip breakers for Wimet tipped tools. Copies may be obtained free upon application.

CODE OF PRACTICE FOR USE OF P.V.C. CABLES, P.D. 202.

THE B.S. Specifications for electric cables were recently extended to include details of polyvinylchloride insulated and/or sheathed cables, this type of cable now being recognised as an alternative to rubber cables. The physical and mechanical characteristics of P.V.C. compounds differ from those of rubber, with the result that the conditions governing the installation of rubber cables, as laid down in the I.E.E. Wiring Regulations, are not entirly applicable to the installation of P.V.C. cables. To meet this position the War Emergency Code of Practice for the Planning of Electrical Installations (B.S. 1062, 1943) has been revised by the issue of an Amendment Sheet P.D. 202.

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The automatic device can be set either for continuous or for single piece operation. A lamp signal, indicating to the operator the time for manual operation of feeding or ejecting mechanism, is arranged above the grinding wheels, where it is easily seen. This automatic device has the advantage that both operating rhythm and rate of stock removal are set by the machine, and thus removed from the control of the operator, thereby increasing output by about 20-25 per cent.

With full-automatic centreless shoulder work grinding machines, as employed for the mass production of screws, bushings, small axles, etc., up to 800 grinding operations per hour can be performed. Machines of this type are equipped with hydraulic in-feed and ejector devices, in-feed times varying from 0.2-3 seconds, according to the number of operations performed per hour. A funnel fed machine for the grinding of small bushes of 3-8 mm. width and 7-25 mm. diameter is shown in Fig. 10. The feeding device of this machine is capable of handling 8000 to 12,000 pieces per hour.

SIMPLE ELECTRIC PRESSURE RELAY

By Dr. Konrad Hoffmann, Leipzig.

(From *Die Chemische Technik*, Vol. 16, No. 9, May, 1943, pp. 84-85).

It is sometimes necessary to pass gases through certain instruments at a constant pressure, or at a constant rate of flow. The first requirement can be achieved to a certain degree of accuracy by means of throttle valves and by getting rid of any excess pressure by pipes submerged in water or mercury. Keeping the rate of flow constant is, however, far more difficult, especially if the resistance to flow varies in the apparatus through which the gas passes. A relay has been developed for this purpose which has proved satisfactory and is relatively simple to make. A description of the instrument is given below.

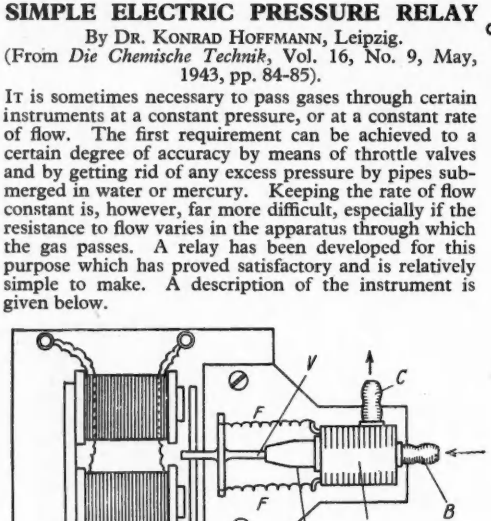

Fig. 1

The actual relay (Fig. 1) is of the pressure type and was operated by an ordinary electric bell unit with two coils. A cylindrical brass piece (M) is fixed to a base plate and screwed into its ends are two inserts (A, B). A long hole of small diameter is drilled in the insert (A), and in which the valve rod (V) is made a sliding. One end of the valve rod is fixed to the armature of the relay. The gas enters through insert (B), shaped conically inside and forming a valve with the rod (V). The valve is kept closed by the springs (F) and the gas leaves the pressure relay through outlet (C). It is advisable to connect the two coils in parallel and not in series to get a larger magnetic pull.

Normally the gas circuit is closed, but if the coils are energised the armature, to which the valve rod is fixed, keeps the valve open until no current passes through the coils and the valve is closed again by the springs.

The relay is operated by a contactor and is regulated according to the amount of gas passing through. In the simplest form a mercury contact manometer can be used to switch off the relay when the pressure in the system exceeds a pre-determined value, or falls below specific limits.

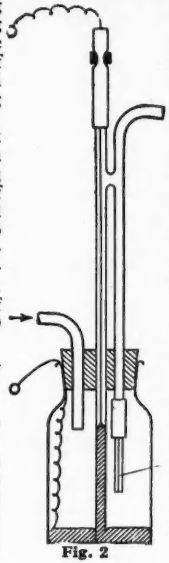

Fig. 2

To obtain a constant rate of flow, a bottle (Fig. 2) fitted with a stopper having three holes may be used, the flow being regulated by means of the pressure drop in a capillary tube. The rate of flow can be varied within close limits by altering the height of the contact wire, a tight joint being obtained by means of a piece of rubber tube and a screw clip. By changing the capillary tube the range of the instrument can be varied to suit conditions.

A general arrangement of the circuit is shown in Fig. 3. An air vessel (V) and two screw clips (Q_1 and Q_2) are inserted between the pressure relay and the contactor, a mercury manometer operates relay (R_1) which in turn actuates the main relay (R_2). The sensitivity of the instrument can be varied widely and adjusted by means of the two screw clips. To prevent sparking it was found desirable to put into the circuit a condenser of about 3μ F in series with a variable resistance of 30-50Ω.

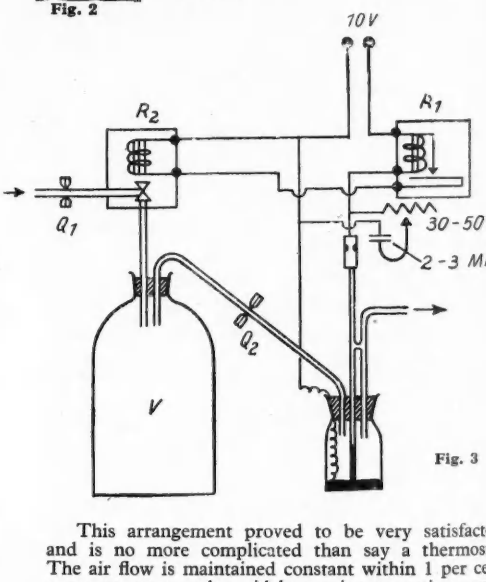

Fig. 3

This arrangement proved to be very satisfactory and is no more complicated than say a thermostat. The air flow is maintained constant within 1 per cent. accuracy, even under widely varying operating conditions.

Figures for the rate of flow of air at 20 per cent., calculated from Hagen-Poiseuille's law are given in Table I.

Table I. Air Flow in cu. cm./sec. against Dimensions of Capillary and Hg- Pressure.

HG pressure cm.	Capillary 20 mm. long			
	2 mm. dia.	1 mm. dia.	0.4 mm. dia.	0.2 mm. dia.
3	4300	270	6.8	0.43
6	8500	530	13.6	0.85
9	12800	800	20.5	1.28
12	17100	1100	27.2	1.71

BUSINESS CHANGE.

Thos. W. Ward Ltd., of Sheffield, have acquired the old established business of John Smith (Keighley) Ltd., manufacturers of Cranes and Stone Working Machinery. The following Directors have been appointed:—Messrs. Frank R. Stagg, M.I.Struct.E. (Chairman); James Bussey, M.I.Struct.E.; G. Albert Smith; W. H. Sharp; and C. A. Lee.

TIN AND ITS USES.

IN No. 15 of the journal *Tin and its Uses*, a new method of tinning cast iron is described which is less complicated than some of the processes hitherto in use. Striking progress has also been made in the manufacture and casting of bronze, and it is suggested that after the war new high-tin bronzes of extraordinary strength, coupled with toughness and ductility, will be available.

Another new development which is ready for extensive commercial application as soon as tin becomes plentiful is speculum plating. Speculum is an alloy of tin and copper which was used in ancient times for mirrors, and which led to important discoveries in astronomy some 150 years ago, when applied to reflecting telescopes. Speculum can now be electroplated on to other metals, e.g., steel. It is being used for the production of non-tarnishing spoons and forks.

On the subject of electro-tinplate it is pointed out that the process of applying tin electrolytically has not magically endowed the metal with two or three times its previous protective value; the protection is, broadly speaking, proportional to the thickness of the tin coating.

This issue also includes an account of the proposed activities of the Tin Research Institute in post-war years. *Tin and Its Uses* may be obtained free of charge on application to the Tin Research Institute, Fraser Road, Greenford, Middlesex, or from the Battelle Memorial Institute, 505, King Avenue, Columbus, Ohio, U.S.A.

PERSONAL.

Mr. Edmund Bruce Ball, Wh.Ex., who for more than a quarter of a century was the managing director of Glenfield and Kennedy Ltd., of Kilmarnock, has died suddenly on Saturday, June 17th, at the age of 71. He was Past-President and Honorary Life Member of the Institution of Mechanical Engineers, and also an Honorary Life Member of the American Society of Engineers.

Col. F. E. Shirley Beavan, general manager of Mountstuart Dry Docks Ltd., and associated companies, has been elected to the Board of the companies. Mr. Beavan is Past-President of the Shipbuilding Employers' Federation.

Mr. R. W. Birch, A.M.I.Mech.E., of the British Electric Traction Co. Ltd., has been appointed Chairman of the Potteries Motor Traction Co. Ltd.

Mr. H. R. Carver has been appointed Sales director of Messrs. Jonas Woodhead and Sons Ltd.

Mr. J. R. Charles, M.I.Mech.E., has resumed his appointment as chief engineer to Messrs. Magnesium Elektron Ltd.

Mr. C. H. Downing and **Mr. H. A. O'Brien** have been appointed directors of British Electric Meters Ltd.

Mr. Wilfred L. Fletcher, A.M.I.C.E., has been appointed Assistant Managing Director of The Tees Side Bridge and Engineering Works Ltd., Middlesbrough. **Mr. F. Cox** has been appointed Chief Engineer of the Company.

Dr. Harold Hartley and **Mr. Lawrence A. Bratt** have been appointed Managing directors of Radiation Ltd.

Dr. J. R. I. Hepburn has been elected President of the Electrodepositors' Technical Society. Dr. G. D. Gardam and Dr. S. Wernick have been elected Vice-Presidents.

Mr. Victor F. Saulet who has been associated with Messrs. Bennis Combustion Ltd. for over 25 years, has been appointed engineer and technical representative on the staff of the Industrial and Engineering Development Association.

Mr. G. Shaw Scott, M.Sc., F.C.I.S., is retiring on the 30th June from the secretaryship of the Institute of Metals, which he has held for the past 36 years. He becomes Secretary Emeritus and **Mr. K. Headlam Morley** will now act as secretary of the Institute of Metals while continuing as secretary of the Iron and Steel Institute.

Mr. James Shearer has been re-elected Chairman and **Mr. David S. Philip**, deputy chairman, of the Glasgow Committee of Lloyd's Register of Shipping.

Mr. C. A. Stephens has been appointed a director of Messrs. A. Reyrolle and Co. Ltd.

Mr. A. G. Telfer has been appointed chairman and joint managing director of the Scottish Non-Ferrous Tube Industries Ltd.

Mr. P. S. Turner, Vice-Chairman of Associated Electrical Industries Ltd., a director of Metropolitan-Vickers Electrical Co. Ltd., and of the British Thomson-Houston Co. Ltd., has died recently.

BRITISH STANDARDS

(Copies can be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1).

BRITISH STANDARD SPECIFICATION FOR ENGINEERING DRAWING OFFICE PRACTICE (B.S. 308).

A REVISED and considerably enlarged edition of B.S. 308 has now been published. The recommendations for standard practice commence with sizes and typical layouts of drawing sheets and the planning, numbering and referencing of series of drawings. Recommended scales, types of line, methods of projection, lettering, dimensioning and sectioning are set down, followed by standard methods of indicating machining symbols, surface finish, screw threads, bolts, nuts, rivets and welds. Notes on structural steelwork, a list of abbreviations for drawings and directions for the preparation of graphs complete the numbered clauses, which are followed by appendices dealing with the reproduction of drawings and the selection, preparation and storage of drawing paper, tracing paper and cloth, and sensitised materials. Other appendices contain references to British Standards for material specifications, general engineering standards and the use of symbols on drawings. The revised edition, which is illustrated with 40 figures and diagrams and four folded plates, supersedes B.S. 308:1927. (Price 3/6 post free).

WIRE STRAND FOR SIGNALLING PURPOSES.

A REVISION of British Standard 163a for galvanised steel wire strand for signalling purposes has recently been published. Experience in the use of the 1936 edition of the specification indicated that amendment was desirable in order to provide strand of greater reliability.

In this new edition several changes have been made.

In place of four grades of wire having tensiles which vary from 25 to 90 tons per square inch, provision is now made for three grades of wire only. The previous low tensile 25/30 ton grade has been omitted and the 40/50 ton grade has been increased in tensile to 50/60 tons.

It is now stipulated that the manufacturer shall test each coil of wire before stranding. The inspection procedure as to the selection of test samples has been modified to ensure that such samples more adequately represent the bulk. Price 2/-.

BRITISH STANDARD SPECIFICATION FOR COLD TWISTED STEEL BARS FOR CONCRETE REINFORCEMENT (B.S. No. 1144).

HITHERTO, reinforcement in the form of mild steel, high tensile steel and hard drawn steel wire, and expanded metal, were the only materials covered, the appropriate specification being respectively Nos. 785 and 405; there was accordingly a need for a specification for mild steel bars which have had their yield stress raised by cold twisting and the above specification has been prepared to meet that need.

The new Specification provided for both single twisted and twin twisted steel bars and the mechanical properties—including the yield point are laid down. The usual clauses dealing with testing procedure, number of tests, etc., are also included. Price 2/-.

WAR EMERGENCY B.S. 1139. TUBULAR STEEL SCAFFOLDING.

THIS Specification provides for two sizes of tubes for scaffolding purposes, a nominal 2" diameter and nominal 1" diameter tube. The Specification lays down details of the requirements with which the tubes should comply, both with regards their dimensions and the mechanical properties. Tests are also included for the right angled couplers to be used with these tubes. It is hoped in a subsequent revision to include tests for other forms of fittings. Price 2/-.

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